Lecture Notes in Educational Technology

Francisco José García-Peñalvo
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Trends on Active Learning Methods and Emerging Learning Technologies

Springer

Lecture Notes in Educational Technology

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Abstracted/Indexed in:

Scopus, Web of Science Book Citation Index

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ISSN 2196-4963 ISSN 2196-4971 (electronic)
Lecture Notes in Educational Technology
ISBN 978-981-19-7430-4 ISBN 978-981-19-7431-1 (eBook)
https://doi.org/10.1007/978-981-19-7431-1

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Acknowledgments

This research was partially funded by the Spanish Government Ministry of Economy and Competitiveness through the AVisSA project grant number (PID2020-118345RB-I00). The authors would like to thank the research groups EtnoEdu of the University of Zaragoza, GRIAL of the University of Salamanca, and LITI of the Technical University of Madrid for their support.

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Chapter 1
Introduction

Francisco José García-Peñalvo, María Luisa Sein-Echaluce, and Ángel Fidalgo-Blanco

As in other areas of knowledge, education must progress and evolve, adapting to new demands, new ways of learning, new ways of managing information and knowledge, and the inclusion of technologies (Alonso de Castro & García-Peñalvo, 2022).

Educational Innovation has marked and continues to mark the path of learning progress in any educational field and level (Fidalgo-Blanco & Sein-Echaluce, 2020). In this book, we work with two key aspects of Educational Innovation: active learning and learning technologies.

Active learning methodologies have always been a challenge (García-Peñalvo et al., 2019), and some have been widely used, such as teamwork (Sein-Echaluce et al., 2021), problem-based learning (Basilotta Gómez-Pablos et al., 2017), or case studies (Ramírez-Montoya, 2015). The incorporation of technologies has generated new active methodologies such as gamification (Villegas et al., 2019), the flipped classroom (Sein-Echaluce et al., 2021), or collective intelligence (Fidalgo-Blanco et al., 2019) among others. Likewise, technologies have transformed both the way of assessing learning (Grande-de-Prado et al., 2021; García-Peñalvo et al., 2021) and decision-making during the teaching-learning process through artificial intelligence (Yu, 2020), big data (Daniel, 2019), and learning analytics (García-Peñalvo, 2020; Hernández-García et al., 2020). Also, digital transformation (García-Peñalvo, 2021; García-Morales et al., 2021), online education (Crisol-Moya et al., 2020; Conde-González et al., 2014), computational thinking (González-González, 2019), and

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_1

Table 1 Responses to question Q1 (previous experience)

Q1—How many educational innovation experiences have you carried out?	
This is my first experience	13.9
I have between one and two years and more than one experience	21.2
I have between three and five years and more than one experience	18.8
More than five years and more than one experience	46.1

open education (Nascimbeni & Burgos, 2019) influence the transformation of active methodologies.

The need for integration of methodologies and technologies was evident during the transformation that teaching and learning processes underwent due to the restrictions resulting from the COVID-19 pandemic (Daniel, 2020; García-Peñalvo et al., 2020). Technology by itself helped, but it also proved to be insufficient to achieve effective learning if only face-to-face classes were transformed into online classes through video-conferencing systems (Hodges et al., 2020; García-Peñalvo & Corell, 2021). Similarly, it was shown that the integration of technologies could open up new learning scenarios by incorporating hybrid methods (García-Peñalvo et al., 2021; Fidalgo-Blanco et al., 2020).

This book aims to contribute to the transformation of learning through best practices that integrate active methodologies with technology, improve the usual learning scenarios, and open expectations for new ones. The chapters of this book correspond to good practices selected and extended from the CINAIC 21—International Conference on Innovation, Learning, and Cooperation held in Madrid from October 20 to 22, 2021, in hybrid mode (face-to-face and online) (Sein-Echaluce et al., 2021).

CINAIC is an academic event that tries to bring the scientific method to develop good practices in educational innovation. Teachers from different educational fields present their latest work in educational innovation, most of them integrating active methodologies with technologies. During the development of the congress, round tables are also organized where different aspects that can contribute to improving educational innovation are analyzed, as well as workshops where methodological and technological trends are shown. Studies and analyses are also carried out, considering the participants' experience in the international conference.

To show the relevance of this book, we include below the results of a study conducted during CINAIC 2021 in which 165 teachers with experience in educational innovation participated, as shown by the percentages of the answers to question Q1 in Table 1. Almost half of the participants (46%) have been applying educational innovation for more than five years and have had more than one experience.

Applying educational innovation has a very different motivation than industrial innovation. While the latter is carried out for competitive reasons, educational innovation is usually carried out by the vocation of teachers to improve student learning and their own decision. Some 55.8% of the participants in the study affirm this, as shown by the answers to question Q2 in Table 2.

Table 2 Responses to question Q2 (motivation)

Q2—What encouraged you to carry out the educational innovation you presented at CINAIC21?	
The innovation services of my university/center	10.3
Other faculty who had already innovated	12.7
The need for educational innovation in my CV	9.7
Improving student learning in my subject area	55.8
Other	11.5

Table 3 Responses to question Q3 (assistance received)

Q3—Where have you found the most helpful in making this innovation happen?	
In the training courses of my university/center	35.2
In similar experiences of congresses and scientific journals	39.4
In social networks	2.4
In open courses (MOOC and OCW)	4.8
Other	18.2

Table 4 Answers to question Q4 (barriers)

Q4—What has taken you the most effort in the realization of your innovation?	
The use of technology	7.3
Methodological change	16.4
Measuring and contrasting results	42.4
Adapting or creating content	26.1
Other	7.8

On the other hand, conferences on educational innovation and dissemination media such as books and scientific journals are the primary source of help for carrying out educational innovation (question Q3). Specifically, 39.4% say so, followed very closely by 35.2%, who say that it is the courses on educational innovation held at schools and universities. All the response options to question Q3 are shown in Table 3.

Nevertheless, methodology and technology are not the main obstacles to carrying out educational innovation experiences. As indicated by 42.4% of the responses, the main obstacle is the measurement and contrast of results, as shown in Table 4, with the answers to question Q4.

Another aspect studied was the transferability of the educational innovation carried out among the different experiences presented. Transferability is a crucial aspect for incorporating the experience of teachers who have innovated in the implementation of new innovations (Sein-Echaluce et al., 2014). In this way, a more significant and faster impact is achieved in the transformation of the learning process.

Table 5 Answers to question Q5 (transferability)

Q5—What do you think is the status of your innovation in terms of transferability?	
Can only be used in my subject	1.2
Can be used in subjects with similar content	21.8
Can be used in any subject of the same subject area	24.2
Can be used in any subject	50.9
Other	1.9

Table 6 Answers to question Q6 (most transferable part)

Q6-What do you think is the most transferable part of your innovation?	
Contents	11.5
Methodology	76.4
Technology	7.3
Other	4.8

Table 7 Answers to question Q7 (motivation)

Q7—What do you think can serve as an indication of the quality of the educational innovation you have done?	
Learning outcomes	55.8
The novelty of the technology or methodology used	3.6
Publication in conferences and scientific journals	10.3
Transferability	27.3
Other	3

Most of the answers to question Q5 about transferability of the educational innovation, 96.9%, indicate that the educational innovation experience is transferable, for subjects with similar contents, in the same area of knowledge or any other subject, the latter being the majority with 50.9% of the total answers. Only 1.2% of the respondents indicated that their experiences were not transferable. Table 5 shows these results.

Question Q6 refers to the part of the experience that seems most transferable. The majority indicated that the methodologies were 76.4%, the contents with 11.5%, and the technologies with 7.3%, as shown in Table 6.

Confirmation of the motivation that encourages teachers to carry out educational innovation can be found in question Q7 on the quality indicator of innovation. 55.8% of the answers favor learning results, followed by 27.3% who believe that it is the transferability itself, as shown in Table 7.

Concerning the aspects that could most help carry out educational innovation, Table 8shows the most usual comebacks. Some 50.3% of the participants in the study indicated that they would have been helped by a definition of indicators known globally to measure the level of educational innovation.

Table 8 Responses to question Q8 (drivers)

Q8-What do you think could have helped you improve the educational innovation you have done?	
Global and known measurement indicators that define the level of innovation	50.3
Salary increasing	3
Increased weight in accreditations	9.7
Decrease in teaching load	24.8
Other	12.2

Thanks to this survey, it can be concluded that:

- The dissemination of this book is appropriate (Table 3).
- The scientific method used in the chapters of the book will help reduce the effort to carry out innovations (Table 4) and improve the innovation itself (Table 8).
- The transferability of the innovation experience is achieved chiefly through the methodologies (Tables 5and 6) used in the book.
- In all the good practices, improvements in learning are achieved, which most motivates the teachers who innovate (Table 2) and is the ultimate goal of their work (Table 7).

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Chapter 2
Improving the Motivation of First-Year Undergraduate Students Through Transversal Activities and Teamwork

David Fonseca, Silvia Necchi, Marian Alaez, and Susana Romero

Abstract Promoting an increase in motivation in first-year undergraduate students not only results in an improvement in their follow-up, performance, and therefore their satisfaction, but can also lead to a reduction in early dropout due to any situation of frustration or poor results. To confirm the initial assumption, the present research work demonstrates how the work of certain competencies in a transversal way allows the first-time student to increase empathy with the degree while improving interpersonal relationships with their peers being an aspect that significantly affects the intrinsic motivation of the student. The chapter focuses on analyzing the results of two transversal tasks carried out through a teamwork process and monitored during the first year of the Bachelor's Degree in Architecture. For the analysis, we used a mixed approach that allowed us to identify the strengths (enhanced in the new iterations) and weaknesses of the proposal on which we are already acting in subsequent replications of these types of transversal activities.

Keywords Transversal competencies · Teamwork · Pedagogical innovation · Educational assessment · Student motivation

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_2

2.1 Introduction

The early years of university degree courses generally provide students with generic learning to equip them with the foundations for more specific subjects. The problem of the heterogeneity found in student entry profiles (Beqiri et al., 2009; Rodenbusch et al., 2016) has been exacerbated by the lockdown in force at the end of the final year of upper secondary education during 2019–2020. This general situation has been linked with issues of student motivation, and studies into the matter are currently being conducted. Online teaching and the consequent lack of person-to-person contact result in low levels of knowledge and motivation which make it harder to follow classes and therefore affect potential performance (García-Peñalvo & Corell, 2020; García-Peñalvo et al., 2020). One way of mitigating the initial impact of this problem on university courses is to design introductory subjects, activities, and/or practical tasks focused more on generic competencies. A more transversal approach to working on specific competencies through more generic methods is directly correlated with better academic performance (Fonseca & García-Peñalvo, 2019; Fonseca et al., 2014, 2015; Necchi et al., 2020; Sanchez-Sepulveda et al., 2020).

The study reported here was conducted under a research project awarded by the Aristos Campus Mundus association (ACM, https://aristoscampusmundus.net/) to investigate how transversal approaches can increase motivation among undergraduate students. The improvements noted are not only limited to motivation, which has been widely proven to be linked to curriculum improvements, but also extend to the level of autonomy of students. Mastering transversal competencies in the course of their studies not only increases students' general competencies but also their future skills (Peña et al., 2016, 2018; Wagenaar, 2014).

The study analyzes and compares two specific activities carried out in year one of the Architectural Studies degree course, in which students are required to hand in a number of tasks completed in teams. These tasks enhance specific subject-related skills in a multi-disciplinary format featuring visits and explanations given on site in areas of action. This type of work forms part of the set of academic activities known as Aula-BCN (Fonseca et al., 2019), which is being included as an active method in the process of change in education called New Learning Context (NLC) (ARLEP LSD, 2020). This process is being implemented at all La Salle schools in Spain, from primary through all intermediate stages to the university level.

Section 2 below looks at the overall context and framework of the project. Section 3 describes the pills assessed. Section 4 sets out the main results and Sect. 5 presents a discussion and conclusions.

2.2 Context

2.2.1 Motivation

Numerous studies (Kahu & Nelson, 2018) have shown that the students entering universities today are very different from those who are now teaching them in terms of both previous skills and their attitudes and motivation to acquire new ones (Bunce et al., 2010). This has led universities to consider the need to take into account students' own characteristics and opinions to enable them to succeed in their studies (Escudero et al., 2016; Fonseca et al., 2017, 2018, 2021; Sanchez-Sepulveda et al., 2019; Villegas et al., 2021). Motivation-enhancing aspects include methodologies for holding their attention, which must be active to substantially improve students' performance (Freeman et al., 2014).

Active student-centered learning methods such Project Based Learning (PBL) have been mentioned by several studies as a solution to increase motivation and competence and decrease dropout ratios (Blumenfeld et al., 1991). PBL has also been found to be better suited to the new challenges of competence-based education, as an approach that allows students to learn while actively participating in the design of the assigned project (Kolmos et al., 2020).

With this methodology, students can acquire knowledge that is more permanent since learning by doing yields more permanent results than simply listening to a lesson. According to studies, students who participate in project-based learning attain higher levels of accomplishment than students who participate in traditional teaching methods (Kolmos et al., 2020; Petchamé et al., 2020; Strobel & Barneveld, 2009).

Besides, PBL is especially suitable for teaching students of architecture degrees, since its approach tries to reproduce the way of working in the architecture field. Working on a common project allows students to better understand architecture as a transversal discipline, where different areas of knowledge contribute to the success of the result.

The PBL is suitable for assessing soft curricular skills such as critical thinking, capacity for analysis and synthesis, strategic planning, leadership and adaptation to teamwork, motivation, and communication, among many, all of them necessary for the professional future (Necchi et al., 2020). Most of the Architecture syllabus includes, besides specific engineering knowledge, other topics that provide an all-round formation. In fact, both specific technical knowledge and non-technical competencies are required including teamwork, communication, problem solving, and leadership skills (ABET, 2019; Chan et al., 2017; International Engineering Alliance, 2014; Passow, 2012; Passow & Passow, 2017).

According to some studies into ways of improving performance, (Partanen, 2020) improvement is even greater with direct interaction with peers and teachers. The character of Aula Barcelona's teaching generates, as the space is different from the classroom, greater cohesion between peers and reinforces links with teachers.

In other words, although students may initially be reluctant to work in teams and fearful of presenting their ideas to their peers, the development of these competencies improves not only their motivation but also the final experience and results (Fidalgo-Blanco et al., 2015; Necchi et al., 2020).

2.2.2 Teamwork Competence

On the basis of these initial premises, a project was designed under the name "Improving social and collaborative competences of undergraduate students using active methodologies. A mixed assessment approach". Funding for this project was approved at the 6th Call for Research Projects organized by the Aristos Campus Mundus association in 2020. The project goal is to develop educational pills based on teamwork and on communicating the ideas to be implemented, without losing sight of motivation. Thus, from the outset of their university courses, students become aware of the enormous potential of teamwork, based on synergies and key points for fostering effectiveness. The underlying idea is that teamwork must be carefully encouraged from the initial formation of groups through to communication and final assessment (Alaez et al., 2021).

This competency, defined as "Actively joining and participating in the attainment of shared objectives with other persons, departments and organisations", can be broken down into three levels. Level one, which is considered to be the most suitable for first-year students, works on the responsibility that team members must show in performing tasks within the time given and in prioritizing team goals over individual interests. Level two deals with participation and involvement in team goals, and level three with ensuring a good atmosphere and team leadership (Fig. 2.1 shows the rubric we have used to evaluate its first level of mastery, following the guidelines of the University of Deusto (Villa Sánchez & Poblete Ruiz, 2007)).

2.2.3 Assessment

To evaluate the pills, the MUSIC® instrument (Jones, 2009) is used. As indicated in its definition, the model weights five indicators that work with different variables that influence a student's motivation, both positive and negative. In turn, MUSIC® also considers the role of the teacher of the course being evaluated and the student's assessment of the proposed learning activities. The MUSIC® has different questionnaires allowing the user to customize it according to the variables to be measured.

The questions that make up the MUSIC® model used are based on the following aspects:

- Usefulness and enjoyment of the activities performed.
- Perception of the importance of the knowledge acquired for their future.

LEVELS OF MASTERY	INDICATORS	DESCRIPTORS				
		1	2	3	4	5
First level of mastery: *Actively participating and collaborating in team tasks and promoting confidence, cordiality and focus on shared work*	Completing assigned tasks within deadline as group member	Doesn't complete assigned tasks.	Partially completes assigned tasks or does so with delays.	Reports before the deadline on the outcome of the assigned task.	Quality of work on the assigned task is a noteworthy contribution to the team.	In addition to completing assigned task well, his/her work orients and facilitates that of rest of team members .
	Participating actively in team meetings, sharing information, knowledge and experiences	Often absent from group work and his/her presence is irrelevant.	Takes little part, mostly at the request of others.	In general is active and participative in group encounters.	His/her work fosters participation and improved quality of team results.	His/her contributions are fundamental for the group process and for the quality of results.
	Collaborating in defining, organising and distributing group tasks	Manifests resistance to the organisation of work within the team.	Simply accepts the organisation of work proposed by other members of the team.	Participates in the planning, organisation and distribution of teamwork.	Is organised and distributes work with effectiveness.	Fosters organisation of work by taking best advantage of team member talents and know-how.
	Focusing on and being committed to agreement and shared objectives	Pursues own objectives.	Has difficulty in integrating personal and team objectives.	Accepts as own the objectives of the group.	Promotes a clear definition of objectives and the group's integration round them.	Motivates and marshals group round more demanding objectives. Groups where he/she participates noteworthy for performance and quality.
	Taking into account the points of view of others and giving constructive feedback	Doesn't listen to classmates and systematically disparages them, wanting to impose own opinions.	Listens little, asks no questions, does not want to know others' opinions. His/her contributions are redundant and not very suggestive.	Accepts the opinions of others and knows how to give own point of view constructively.	Promotes constructive dialogue and inspires quality participation from other group members.	Integrates others' opinions into a higher perspective, maintaining atmosphere of collaboration and support.

Fig. 2.1 Rubric for assessment of the generic competency of Teamwork, level 1 (Villa Sánchez & Poblete Ruiz, 2007)

- Ability and control of the student to perform the tasks successfully and obtain a high grade.
- Attractiveness of the teaching methods used.
- Support and attitude of the teacher in the performance of the practice.

The obtained parameters are quantitative and are widely validated (Fonseca et al., 2016, 2017; Valls et al., 2017; Villegas et al., 2021), although the model stresses that they should be considered independently.

2.3 Project Description. Methodology

This proposal has been gradually honed since it was first published in the academic year 2016–17, and in a more coordinated fashion in 2017–18 (Centeno Hernáez, 2018; Fonseca et al., 2019). The practical tasks set involve activities organized following site visits/routes to locations to provide a context for them with the help of teachers of different subjects. These site visits are intended not just to enhance synergies between subjects and teaching staff but also to spark interest and improve teaching methods based on actual case studies, moving architectural concepts outside the classroom setting. The activities are set out to reinforce motivation in first-year students in an indirect fashion, so that even though the early part of their course comprises largely basic, more instrumental subjects they can still glimpse the potential extent of their chosen profession. This is intended to help decrease year one dropout rates.

This proposal falls within the lines of action of the "New Learning Context" (NLC), a new teaching model based on active learning methods that is currently being implemented internationally at establishments of all types linked to La Salle (primary, secondary, upper-secondary, vocational training, and university education) (ARLEP LSD, 2020; Salle, 2018). La Salle Campus Barcelona (Universitat Ramon Llull) and La Salle Campus Madrid were among the 104 centers involved in the design and execution, which began in 2018.

The concept learning environment was widely studied and analyzed from different academic viewpoints, e.g. (Land & Hannafin, 1996; Moore et al., 2011). A learning environment, according to the NLC, is a pedagogical setting that combines all the elements that students require to obtain their learning outcomes in a holistic manner. As a result, the learning environment is an important component of the NLC educational approach. The environment can be thought of as a separate space with its own educational goal in terms of approach and teaching. NCL learning environments are Seminar, Workshop, Project, Welcoming, and Closure (Petchamé et al., 2021). Project is a key learning area at the NLC, where students develop skills by completing complex assignments. These projects are characterized by their transversal knowledge integration, which is created in an interdisciplinary manner using a variety of sources (scientific, social, historical, artistic…). Projects normally focus on one source, which is then complemented by the others, resulting in a learning environment in which students may effectively develop and construct knowledge.

This paper focuses on the way in which two of the pills developed are implemented and analyzes the results for the case study involving transversal visits in year one of Architecture.

2.3.1 Pill1: Sagrada Familia Schools. Historical Context

Le Corbusier visited Barcelona in 1928. From here, he began a period of collaboration with the GATCPAC (the Spanish acronym for Grupo de Arquitectos y Técnicos Catalanes para el Progreso de la Arquitectura Contemporánea), which allowed young Catalan architects to contact the master, notably Josep Lluís Sert and Antonio Bonet. It seems that this is where the use of the "Catalan vault" comes from in some projects, such as Le Maison Jaoul. It is known that he took advantage of his stay in Barcelona to visit La Sagrada Familia, and that he noticed a modest building next to it, the schools. We know it because, among the notes he took, there is one of these buildings. Perhaps the Chapel of Ronchamp and other projects find their origin here … Years later he wrote: "*What I saw in Gaudí was the work of a man of extraordinary strength, faith and technical ability … Gaudí was an artist; only those who touch the sensitive hearts of men remain forever. It means the architecture that triumphs over all the problems gathered in the line of fire (structure, economy, technique, use), thanks to an unlimited interior preparation of observation. Architecture is the fruit of character, just that: a manifestation of character*."

Antoni Gaudí was born in 1852 in Reus and died in 1926 in Barcelona. In 1883, he was appointed architect of La Sagrada Familia in place of Francesc de Paula del Villar i Lozano, who initiated it. The schools are a construction of 1909–1910, a temporary, inexpensive, and quickly executed building to solve a need: to educate the children of the Temple workers. Their own location, within the site where the Sagrada Familia was built, condemned them to disappear as the works progressed.

In 1939 and 1938, schools were burned and rebuilt in 1940 by Francesc de Paula Quintana and Vidal, one of the architects who subsequently directed the work of the Temple. In 1995 the growth of the Temple coincided with the physical space of the schools, mutilating them. In 2002, the construction board of the Temple relocated the schools to their current location, in front of the Passion façade, rotated 90º with respect to the original location. Like everything that surrounds Gaudí, passions and controversies have been happening, and his schools have not been exempt…

2.3.2 Pill1: Sagrada Familia Schools. Work and Aims of the Practice

The practice consists of making a model on one of the ruled surfaces that Gaudí uses, in schools or in the Sagrada Familia (Adell & García Santos, 2005). The ruled surfaces are.

- Hyperbolic hyperboloid (main altar).
- Parabolas and funiculars (section).
- Hyperbolic paraboloid (cloister).
- Conoid (schools' roof and walls).
- Helicoid (towers stairs).

The delivery format of the model was free, and it must fit on a rigid support measuring A3 (29,7 × 42 cm). Graphic information and images that serve to identify the position of the surface in the buildings studied and the components of the group must be incorporated into the same support. The models should be used to study the geometric figures that originate them and the generating lines that form their surfaces. The pedagogical objective is to understand them from an analytical vision and to reason how they could be executed, especially with the technology of the moment that they were made or thought about. The same difficulties of the model must serve to express this research. The calendar of this activity was as follows:

- Session 1: Visiting and drawing activities, discovering the environment and schools.
- Session 2: In the classroom, work addressed to geometric conceptualization and peculiarities of the assigned surface.
- Session 3: In the classroom, choice of material, trial of scale, and distribution of tasks.

- Session 4: In the classroom, time for making the model.
- Session 5: Hall of the school: Delivery of models, assembly of exhibition, comments, and assessment.

For a better understanding of the location of the schools, the following explanation about the planning of the site was done:

La Sagrada Família (The Holy Family) is an expiatory temple, erected with donations from parishioners to get forgiveness for their sins. The initial idea came from José Mª Bocabella, who founded the Spiritual Association of Devotees of San José with the aim of raising funds.

The construction began in 1882, with a neo-Gothic project of three naves by the architect Francesc de Paula del Villar Lozano, but due to disagreements with Bocabella, he abandoned the work and in 1883 the young architect Antoni Gaudí, who had worked with him, took over. Gaudí changed the project, but could not modify the orientation, since the foundations were finished and the construction of the crypt had begun. The works continued on the crypt, the apse, and the Nativity façade.

Gaudí worked on this work for 43 years, the last 15 exclusively, until he died in 1926, hit by a tram. The works continued and were directed by his collaborators at the beginning and by successive architects appointed by the board of the Temple later. Gaudí left models and some drawings, but he used to make them as work progressed. He was not raising all the perimeter walls at the same time, but his idea was to complete one entire facade after another, so that the donors would see results.

The land was located in San Martí de Provençals (which at that time was an independent municipality of BCN and added to the city in 1897). It was included in the Pla Cerdà of expansion of the city approved in 1859. The dimensions of the site were somewhat greater (130 $\times$ 120 m) than Cerda's blocks (113.3 $\times$ 113.3 m) since it was a land reserved for a hippodrome that was never built. Gaudí proposed distribution of the open spaces around the church: first in the form of an orthogonal star and then rotated to open up diagonal views toward the church so as not to lose building capacity in the adjacent blocks. The 1917 General Plan of Barcelona, based on the previous Jaussely Plan of 1905 for the embellishment of the city, was drawn up to join the expansion with San Martí. This plan established two spaces on either side of the church, which were never executed. Gaudí complained that the new plan had only one open space in front of the Passion Gate. In 1925, the expansion plan of San Martí by Ubaldo Iranzo placed two squares on the Passion and Birth's facades, and the subsequent planning preserved them as green areas. The first is the Plaza de La Sagrada Familia, inaugurated in 1928 and designed by the landscape architect Nicolau Maria Rubió i Tudurí. The other, Plaza Gaudí, by the same architect, was not finished until 1981, once the buildings that occupied it were demolished.

Today, the Temple is limited to a block between the streets Provença, Mallorca, Marina, and Sardenya. In order to complete the work, the exterior spaces needed to be tidied up, as they come into conflict with the surrounding area. Attempts to free up space for the doorways at the foot of the building have been controversial, as the adjacent block is consolidated and would entail its demolition. This, added to the

Fig. 2.2 Class visit to the Sagrada Familia Schools (Photo original from authors)

pressure of the massive presence of tourism, has led to the drafting of a Special Plan for the Integral Urban Planning of the Temple with the participation of all the agents involved and the residents of the neighborhood.

This practical task is monitored in the following subjects: Physics I, Architectural Analysis, Graphic expression, and Mathematics and Descriptive Geometry (see Fig. 2.2 with the students at the visit place).

2.3.3 Pill 2: 22@, from the Plaza "Les Glories" to the Sea. Historical Context

With the advent of democracy in the city councils in 1979, the town council of Mayor Narcís Serra appointed Oriol Bohigas as Town Planning Delegate for Barcelona City Council. There was a period of strong public investment in the city that led to a change in its appearance, and to the international projection of Barcelona. Oriol Bohigas is a key figure for his ability to guide these investments, which will culminate in the milestone of the 1992 Olympic Games. Among the numerous interventions of this period, the Olympic Village stands out for its proximity to the area where we are standing. This became a new district of the city facing the sea. The culmination of the Olympic Village allowed us to discover the potential that lay next to the Poble Nou neighborhood. Cities have taken advantage of major events to undertake urban redevelopment actions, such as the Fòrum de les Cultures (2004). Taking the Fòrum as a starting point, the entire Besós area has been recovered, the entire Poble Nou district, occupied by disused factories, is being regenerated, and the Diagonal Mar district has been built, providing the city with new parks and leisure spaces for citizens. The area of intervention described is very ambitious; it is delimited by the triangle between the Diagonal from Plaça de les Glòries, and the sea (Bottero et al., 2020; Jutgla & Pallares-Barbera, 2015; Pique et al., 2019).

All these actions have led to a change in the appearance of the city's seafront. The action that closes this transformation to the north of the seafront is the multipurpose esplanade designed by José Antonio Martínez La Peña and Elías Torres (2000–2004), which culminates with a large photovoltaic panel that connects with the city of Badalona. District 22@ covers an area of about 200 hectares. New urban planning instruments have been deployed with the aim of transforming the old industrial land of Poblenou (Sant Martí district) into an area of strategic concentration of knowledge-intensive activities. At the same time, 22@ is creating a new compact city model where companies, universities, research, training, and technology transfer centers coexist with housing, facilities, and green areas. In order to achieve this goal, projects are developed to promote competitiveness and international projection in strategic sectors: Media, Information and Communication Technologies (ICT), Medical Technologies (TecMed), Energy, and Design.

2.3.4 Pill 2: 22@, from the Plaza "Les Glories" to the Sea. Practical Task

Organizing a territory means giving it a specific structure and intervening on existing terrain to create a new territory. Organizing also means arranging things to achieve a specific purpose, i.e. setting up rules to bring together different parties and integrate them into the territory. The practical task set here comprises a volumetric and cross-sectional study in an area close to the facilities of the Forum in Barcelona. Students are asked to model all the buildings in the area and the land elevations as far as sea level, including the whole breakwater and Ronda Litoral area with different basic volumes. The purpose of the analysis is to identify the core ideas in this non-urbanized area of the city with a view to designing a future surfing campus (the final project in the subject of Architectural Analysis), in the work area indicated in Fig. 2.3.

Fig. 2.3 Work area for the visit (Forum). (*Source* Google Maps, edited by the authors)

Specifically, students must generate individual, solid volumes for each element in the study area, organized by type of material or use, a single, overall volume representing the whole study area, and an automatic, basic cross-section of both the individual and overall volumes. They must also create a post-edited detailed 2D cross-section showing thicknesses, vegetation, and street furniture, and a location plan to scale. These must be handed in on two horizontal DIN A3 sheets, with free composition. It is necessary to customize the location plan:

- Modify the block of the trees, line value, shading, etc. (with clear graphics for each project.)
- Floor plan with the analysis conclusions of the environment (identification of the initial ideas of the project). The scale in dinA3 will be the one that best fits the overall presentation (e.g. 1/2000 and with expanded details, if necessary).
- Axonometry (in perspective) showing the differentiated and semitransparent volumes, which allows us to understand the environment from the residential tower to the sea line.
- Sectioned axonometry (orthogonal or perspective), looking at Badalona, where the section is clearly marked. In this case, the model will be shown with all the volumes joined.
- Post-edited 2D section with detail, thicknesses, vegetation, and urban furniture. It will be sectioned in the middle of the building in the landscaped area, up to about 20 m past the sea line. The scale to be presented in dinA3 will be the one that best fits the global presentation (1/500 or 1/1000).

The calendar to do this activity was.

- Session 1: Tour and discover the @22 district.
- Sessions 2, 3, and 4: In classroom, time for working in Analysis classrooms and Computer Tools practice sessions.
- Session 5: Delivery and exposition. Comments and assessment.

2.4 Results

The sample is taken from the answers given by 26 first-year students (out of a total of 48, i.e. a response rate of 54.16%), who filled in the anonymous assessment survey freely after receiving the necessary information. The questionnaire had 4 dimensions: the first one related to the functioning and perception of the class-visit (pill), the second one related to the practical work associated with the activity, the third one focused on the evaluation of the group work, and finally the implementation of a reduced MUSIC®.

Table 2.1 shows the comparative assessments of the two activities given by students.

We want to highlight the variable Explanation (in bold in Table 2.1), as it is a composite result of the various subjects explained in each visit. In this sense, for Pill 1, the scores fluctuate from 2.23 (SD: 0.86) for the explanation of Graphic Expression

Table 2.1 Perception about the visit-activities using a Likert scale of 5 points (1—completely disagree/unsatisfied to 5—fully agree/satisfied)

N = 26	Pill 1		Pill 2	
(Av: Average; SD: Standard Deviation)	Av	SD	Av	SD
Previous Data (location, schedule, logistics)	3.31	1.05	3.57	0.53
Aims of the visit	3.00	1.10	3.00	1.15
Usefulness of this type of activity	3.46	1.03	4.14	0.90
Explanation	3.04	1.15	3.11	1.10
The explanations have improved my knowledge	3.23	1.14	3.86	0.90
My level of attention has been higher compared with regular activities	3.31	1.23	3.43	1.40
I have understood the relation between subjects	3.73	1.04	4.14	0.90

through 3.14 (SD: 1.20) for Architectural Analysis, and up to 3.65 (SD: 1.32), for the explanation of Geometric Descriptive and Mathematics. In the comments on the questionnaire, the students highlighted the following negative aspects that explain the low score of the first subject: lack of order in the explanation (12 students), differences in explanation between subgroups (national and international) due to time of explanation (7 students), and apparent lack of script and/or relation with the rest of the subjects (6 students). At the opposite pole (the "Wows!"), the good perception of the explanation of Mathematics and Descriptive Geometry is associated with comments such as clear relation with the statement of the subsequent practice (10 students), discovery of aspects not visible at first sight in the buildings (9 students), and clear and similar explanation between groups (5 students). In summary, and considering the scores obtained, it is evident that it is necessary to improve the previous explanation of the purposes of these types of activities, as well as to generate a script in the presentation that is related to these purposes and to the practical statement, all this so that the student is clearly oriented. This is a fundamental aspect in a first-year student so that their motivation does not quickly decrease, because it is clear that the student's understanding of the links between subjects as well as the usefulness of this approach (items 3 and 7 of the questionnaire) have been clearly identified by the students.

In the case of Pill2, up to eight explanations were given at different points along the route. This time they were not linked to specific subjects but to the architectural-tectonic relationship of these spaces (Canopia Urbana, Los Encants Market, Design Museum, Agbar tower, MediaPro building, MediaTIC building, Can Framis garden, and the location site at the beach of the practical project) with the environment (see Fig. 2.4).

The variable Explanation in Table 2.1 weights all of them, from the lowest score (MediaPro building, with a score of 2.71, SD: 1.50) to the highest (3.43, SD: 0.79 corresponding to the area of practical work in the beach area). As in Pill 1, the aims of the visit were the least valued variable by students, with the same score of 3.00 (SD: 1.15), followed by the explanation, which improved, but not significantly (3.11, SD: 1.10).

Fig. 2.4 Eight locations of the Pill 2

If we compare the overall assessment, an increase is observed in the second Pill, with an average of 3.60 (SD: 0.98) on all the variables studied, compared to 3.29 (SD: 1.10) in the first Pill. The difference is not significant (with a two-tailed P(T) of 0.144), but it shows how teachers were able to adapt to the second visit by focusing on the weaknesses identified in the first one. The usefulness of the explanations and the links between subjects are the most highly valued items again. These, together with the statement that the explanations have improved the students' level of knowledge (all of them with a significant increase), demonstrated the usefulness and capacity for improvement of the educational proposal.

The next dimension analyzed focused on the students' assessment of the practical exercise resulting from the visit (Table 2.2).

As can be observed, nearly all the indicators have obtained a large increase in the second activity, which clearly exceeds the first average (Pill 2: 3.37 vs. Pill 1: 3.09, SD: 1.22 and 1.48, respectively). This increase has been reduced due to the indicator of the time allocated for the practice (second in the list), the only one that has significantly decreased in the last activity, going from 3.69 to 3.14.

Table 2.2 Assessment of the practical exercise after the visit using a Likert scale of 5 points (1—completely disagree/unsatisfied to 5—fully agree/satisfied)

N = 26	Pill 1		Pill 2	
(Av: Average; SD: Standard Deviation)	Av.	SD.	Av.	SD.
The statement has been clear, concrete, and specific	2.73	1.31	3.00	1.15
The time assigned has been adequate for the practice	3.69	0.93	3.14	1.57
The support/additional classes to carry out the work have been adequate	2.85	1.26	3.00	1.15
The format of the final delivery has been consistent and appropriate	3.50	2.69	4.29	1.25
The supporting documentation for the practical activity has been adequate	2.69	1.23	3.43	0.98

Fig. 2.5 Five models handed in, representing different types of surfaces. Deliverables for Pill 1

In this sense, the size of the work area, the need to personalize the information in this area, and the fact that it was the last practical activity before the exams are aspects reflected in the comments that explain this reduction. On the other hand, the possibility of digital delivery, without the need for print-outs or other formats such as mock-ups that require high development times and economic costs, is clearly seen as the most positive aspect of the practice with a weighting of 4.29 out of 5 (SD: 1.25) with a significant increase in the student's perception with respect to the previous delivery. The support documentation for the visit is the other indicator that increases significantly and is related to the need to establish a script and clear purposes for this type of transdisciplinary activity.

Figure 2.5 shows the work from the Sagrada Familia school exercise on display and a selection of five models handed in.

Figure 2.6 shows two examples of the work handed in for exercise of Pill 2 of the 22@ and Forum zone, with enriched sections, 3D viewpoints and 3D modeling.

In the third dimension, we have analyzed the practical work and task distribution done in teamwork (see Table 2.3). Two aspects are clearly identifiable: we are in front of the block with the highest overall score (Pill 1: 4.71 vs. Pill 2: 4.78, SD: 0.76 and 0.43, respectively), and the slight increase in the second activity is not significant, beyond the reduction in the dispersion of responses identified from the average value of the standard deviation. These results demonstrate the high interest, motivation, and degree of satisfaction of the students in well-guided teamwork. To achieve this, it has been necessary to carry out specialized training and a first practice that has identified the shortcomings and needs of this type of work. However, we cannot forget the social component of teamwork. As the course progresses, students form groups according to their interests and these associations tend to be much more effective and efficient, as the study shows.

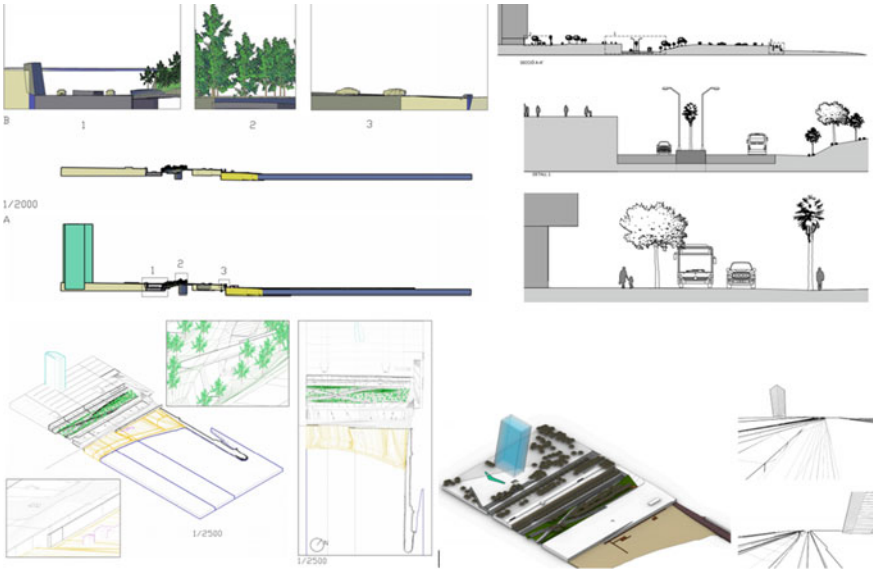

Fig. 2.6 Example of enriched sections and perspective and/or axonometric views of submitted drawings

Table 2.3 Teamwork assessment using a Likert scale of 5 points (1—completely disagree/unsatisfied to 5—fully agree/satisfied)

N = 26	Pill 1		Pill 2	
(Av: Average; SD: Standard Deviation)	Av.	SD.	Av.	SD.
I have completed the tasks assigned within the group into the deadlines	4.62	0.80	4.70	0.46
My group has performed the tasks assigned into the deadlines	4.73	0.72	4.86	0.38
I have participated actively in the meetings of the team, sharing information, knowledge, and experiences	4.65	0.89	4.71	0.49
My group has actively participated in the team's meeting	4.63	0.94	4.73	0.51
I have collaborated in the definition, organization, and distribution of group tasks	4.88	0.43	4.88	0.48
My group has joined together in the definition, organization, and distribution of group tasks	4.77	0.82	4.91	0.43

Finally, we used the validated MUSIC® instrument for the study of student motivation, as indicated above. In our case, we have made a simplification based on 9 questions covering all the dimensions studied by the instrument ("M: eMpowerment": M6; "U: Usefulness": Average M1 and M8; "S: Success": Average M2 and M5; "I: Interest": Average M3 and M4; "C: Caring": Average M7 and M9), using the following questions/assertions:

Table 2.4 MUSIC® values comparison (based on a Likert scale of 6 levels)

Pill 1					Pill 2				
M	U	S	I	C	M	U	S	I	C
4.26	3.90	4.75	4.05	4.17	4.29	4.00	4.07	3.86	4.35

- M1: In general, the planned activities of the course are useful.
- M2: I am confident in my ability to successfully carry out the established activities.
- M3: The described teaching methods actively involve me in the course.
- M4: I think I'm going to enjoy the course activities.
- M5: I consider myself able to get a high grade on the activity.
- M6: I have control over how I learn the contents of the course/activity.
- M7: The teacher cares about my performance in the course.
- M8: I believe that the knowledge achieved in this course is important for my future.
- M9: The teacher is friendly/understandable.

The comparative results of MUSIC® can be seen in Table 2.4.

The only value with a significant difference ($p = 0.045$) is identified for the task success variable (S). This variable refers to the ability to successfully perform the practice. It is logically related (its decrease for the second activity) to the size of the space to be represented and the freedom given in terms of taking measurements, representation, and decision-making about the space. While in the first activity, the work guidelines were very clear and precise, the differential factor in the second activity, that of ambiguity in decision-making and representation, was quickly identified by the pupil as a possible lack of ability to obtain a successful result. In this sense, and with the aim of improving this practice, it is clear that in future iterations it would be necessary to show previous examples, limit the work area, and/or give the student more time for corrections prior to delivery. All of this could be complicated if it is scheduled at the end of the academic year.

There is also a clear need to improve the explanation of the usefulness of each visit and its practical work (U: 3.90 and 4.00), which is directly related to student interest (I: 4.05 and 3.86). These two items were the lowest rated in MUSIC®. In this type of activity, it is easy for the teachers to demonstrate their great knowledge of the city and the urban project by talking and explaining too much which makes it difficult for the pupils to perceive which aspects are fundamental for their practical work and, ultimately, the grade for the exercise. In the first year, students are more motivated to pass the subjects rather than to acquire new knowledge and architectural culture, given that many vocations have not yet been established in a secure and stable way. Reducing, targeting, and scheduling visits with explanation times and linking them to practical activities seems to be essential to improve activities that, from the outset, meet with the approval and interest of the learner, compared to traditional activities.

2.5 Conclusions

Maintaining and, if possible, increasing the motivation of first-year undergraduate students is essential to avoid possible early dropouts. In this sense, the importance of promoting transversal competencies versus specific ones has been noted, so that the student's adaptation to the chosen degree program is gradual and positive. To this end, the design and implementation of transversal activities between subjects is a strategy that allows the student to identify the interconnection of content. This identification is very important as it reduces the possibility of abandoning those subjects with complex technical specifications, as their relationship with the rest can serve as a support mesh between contents.

The methodological approach explained in this chapter intends to precisely influence the aforementioned aspects. It is based on the implementation of the NLC in all the La Salle centers in the ARLEP region and has been applied in the specific cases of the degrees in Architecture and Technical Architecture and Building. A number of transversal and multidisciplinary activities were created in the first year of the degree, so that some of identified generic and specific competencies would be evaluated by means of a rubric. The grade obtained from each exercise (from the average evaluated by each subject according to its learning objectives) has the same weight in each subject (10%).

The design of each activity/visit is based on a dossier that the student has in advance with information about the visit, photos and complementary texts, and space for drawings, sketches, and notes. The visit is made to a singular building or an urban area. The different teachers of the different subjects who accompany the groups explain the differential and necessary elements for the understanding of each subject to be explained in each subject. Finally, they form group work (from 2 to 4 students) for approximately one or one and a half months. Each of the groups must develop a deliverable that relates both the concepts explained and other new ones that the group members must relate to.

The results of the activities presented and monitored allow us to affirm that student motivation in these types of activities is very high and satisfactory. Likewise, the detail of the sampling carried out makes it possible to identify the weaknesses of each visit as a whole, as well as of each specific explanation. This aspect is fundamental so that the activities can be improved in each iteration in terms of design, explanation, formulation of objectives, and practical part. This is clearly observed when comparing the last activity with the first one evaluated.

Not only does the methodology used allows students to adapt progressively to the contents of a subject, which is very important in the first year of a degree, but it also improves their transversal skills, such as teamwork, which is so important in degrees related to Architecture and Construction. On the other hand, it provides the teaching staff with a tool for active monitoring of their activities in order to improve and adapt them for better development.

Acknowledgements This study is funded under the project "Improving social and collaborative competences of undergraduate students using active methodologies. A mixed assessment approach", awarded at the 6th Call for Research Projects by Aristos Campus Mundus (ACM) in 2020, under ID code ACM2020_02.

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Chapter 3
Conceptualizing a Teacher Training for Identifying STEAM-Lab Spaces to Address Diversity Gaps

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Abstract Nowadays, the diversity gap in STEM, with a special focus on the gender gap, is a worldwide challenge. A sustainable society cannot be achieved until society is represented in the STEM sectors that have such an impact on its development. The CreaSTEAM project is focused on mapping best practices in STEAM and

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_3

creating STEAM-Labs in secondary schools in order to reduce diversity gaps, for example, gender, social or cultural background. With the aim to create adequate spaces according to the characteristics and possibilities of schools, this chapter addresses how to design and implement a training process for teachers and institutions that allows the design and implementation of STEAM-Labs in educational centers.

Keywords Teacher training · Diversity gap · STEM · STEAM · STEAM-Labs · Secondary schools · Erasmus + project

3.1 Introduction

Lack of diversity, particularly gender inequality, and social background are some major challenges in multiple areas, but they are common in STEM education (Science, Technology, Engineering, and Mathematics), from primary school to university level, and thus in the labor market (Aguilera & Ortiz-Revilla, 2021; Conradty & Bogner, 2019). When we address diversity, we are concerned about attracting people from all walks of life, from various cultures, disabilities, ethnic groups, gender, economic, and sexual orientation. We also speak of inclusion when the demands of some groups are not effectively met (Lee et al., 2014; Winters, 2013).

A low diversity in STEM studies, but growing, has been identified as one of the main problems that need to be resolved in order to reduce the diversity gap that exists in these sectors (Conde et al., 2021; Garcia-Holgado et al., 2020). Since the 1980s, there have been numerous reports of challenges with science and mathematics education (Bang & Medin, 2010; Klassen, 2006), as well as recommendations for educational changes such as active learning, project participation, and implementing mentorship (Fonseca & García-Peñalvo, 2019; Fonseca et al., 2018; García Peñalvo & Colomo Palacios, 2015; Lõpez-Nicolás et al., 2014; Petchamé et al., 2020; Romero et al., 2020; Sanchez-Sepulveda et al., 2019; Villegas et al., 2019). These efforts, on the other hand, do not try to improve the status of students who have a lower representation in these locations.

Gender is the key diversity gap that has been addressed in prior research on STEM approaches. We may remark that historically, there are notably less women in STEM-related studies and professions (Botella et al., 2019), which has sparked

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global interest in improving female vocations and moving closer to gender parity as a global goal of governments and educational institutions. Studies such as the Trends in International Mathematics and Science Study show that only one-third of women pursue higher STEM education (Frey, 2018), possibly due to the subjective influence of their previous teaching references, where male teachers tend to teach STEM subjects and female teachers tend to teach social or linguistic subjects. In this regard, the gender gap in STEM studies is one of the most significant challenges facing local, regional, national, European, and global institutions, highlighting the empowerment that the European Union is attempting to address through the development of support and funding programs with various organizations (Astegiano et al., 2019; Burke & Mattis, 2007; Chiu et al., 2018) such as the European Platform of Women Scientists, the European WITEC Association, and projects such as SESTEM or GENDERA (García-Holgado et al., 2020).

Moreover, most of the projects propose actions, academic interventions, new tools, learning materials, resources, and strategic plans; but there is a lack of projects that consider innovation and creativity as an inherent part of STEM areas. Namely, most of the projects are focused on STEM instead STEAM (Science, Technology, Engineer, Arts, and Mathematics). Nowadays, it is important to take into account this transformation from STEM to STEAM. The twenty-first century demands breathtaking innovation (Maeda, 2013). Problem-solving, fearlessness, critical thinking and making, and creativity are skills related to innovation processes not only in STEM areas, but also historically associated to arts. In this sense, arts hold great potential to foster creativity and new ways of thinking that can help unleash STEM innovation (EducationWeek, 2011).

In this context, the CreaSTEAM project aims to address diversity and social inclusion in order to develop welcoming environments for STEAM education (Moreira et al., 2019; Sáinz et al., 2020; Te & Degol, 2017; Tzu-Ling, 2019). In this way, the CreaSTEAM actions will support innovative and open pedagogies in education that promote equality and diversity through an innovative approach based on the STEAM-Lab concept, which combines characteristics from other specific typologies of professional laboratories, such as Fab-Labs, Media-Labs, and User-Labs. In this innovative space, the aim is to train good practices in order to promote diversity in STEAM. The STEAM-Lab's emphasis is not to train students in applications and technologies, but rather to develop interdisciplinary projects to reduce the gap in STEAM studies and vocations. To this end, teachers are a fundamental piece of the puzzle (Boice et al., 2021; Conradty & Bogner, 2020; Kang et al., 2012). They will be the ones who will manage the possible spaces and uses (practices or projects) focused on two possible objectives: either to identify and reduce any kind of diversity gap in their classes, or to train their students in the current gaps that can be found, either in their social environment or in other nearby environments (local, regional, national, or international). Either approach is likely to be a step forward in improving STEAM vocations, especially in those groups affected by diversity issues (Arthur et al., 2017; Feichas, 2010; Terry, 2016).

For these reasons, this chapter focuses on the design and implementation of training for secondary school teachers in the countries that make up the consortium

(Spain, Italy, Turkey, and Germany), with the aim of making it scalable to any school in any country that wishes to implement a STEAM-Lab in its school in the future. This training is aimed at enabling teachers to identify both the potential spaces in their schools and the technologies that could have a greater impact on improving STEAM vocations and the potential gaps identified among their students and/or that they want to improve their students' knowledge. In addition, the training will help teachers to be able to identify behaviors, practices, and situations that could potentially create or enhance gaps to be solved in each class (Brantlinger et al., 2020; Ferrada & Pino, 2020; Starck et al., 2020). The training designed and implemented also encountered a very relevant handicap: The COVID-19 pandemic. Due to mobility restrictions, the training initially planned as five face-to-face days was divided into two online/virtual training periods: two days in May 2021 and two days in September 2021 according to the design and specifications that we will see throughout the chapter.

3.2 Context

3.2.1 The Project

CreaSTEAM is the acronym of the project "Co-thinking and Creation for STEAM diversity-gap reduction" (ref.: 2020–1-ES01-KA201-082,601) which is co-financed by the Erasmus + program of the EU in its 2020 call (Oct-2020 to Sep-2022). The consortium is formed by seven partners with three types clearly identified:

(a) Universities and Research Groups (main strategy and coordinating all actions): La Salle, Universitat Ramon Llull: GRETEL Research Group (Spain), and University of Salamanca: GRIAL Research Group (Spain).
(b) Three National/Regional institutions (coordinating educational strategies): Federazione Istituti di Attività Educative (FIDAE) (Italy), Bursa İl Milli Eğitim Müdürlüğü (Bursa MEM) (Turkey), and Studienseminar (Studienseminar GHRF) (Germany).
(c) Two schools: Sadettin Türkün Ortaokulu (Turkey), and Clemens-Brentano-Europaschule (Germany).

In addition, and as a functional valorization strategy, contacts were established with a number of schools in all consortium countries during the first year of the project. The aim of these contacts was to involve these schools as associated partners, with the objective of implementing their own STEAM-Labs and participating in the process of creating and monitoring good practices in diversity. In the first year of the project, up to 12 schools have formalized this collaboration, and thanks to the networks of the various centers, a similar incorporation is expected throughout the second and subsequent years of the project.

The CreaSTEAM project's main objective is to reduce any diversity gap and improve the motivation and vocations of students through STEAM interdisciplinary

projects and practices to be developed in a new space in the schools called STEAM-Labs. In this sense, two Intellectual Outputs (IO) were defined as follows:

- IO1: Key concepts and strategies for designing and implementing a STEAM-Lab. Training and co-design of STEAM-Labs in the schools as well as the realization of some pilot STEAM projects.
- IO2: Propose a framework for schools and educational institutions to design, execute, and analyze STEAM activity packages in partnership with local communities and organizations for reducing any diversity gap identified.

In short, the CreaSTEAM project's concrete goal is to create supporting documentation that identifies, details, and allows replication of recent and innovative proposals addressed in various international environments where STEAM approaches are being used to close diversity gaps and increase professional vocations within the profiles affected by such gaps. In this regard, the future guide should include best practices for building, developing, and implementing STEAM projects and spaces, named the STEAM-Lab, all while keeping five key principles in mind: school infrastructure, curriculum implementation, school culture, instruction, and outcomes., which are inspired in the School Key Elements and Criteria from Scientix (2021).

3.2.2 The Teacher Training in COVID Times

Any educational innovation or change requires a previous and very important step: teacher training (Schneider & Preckel, 2017). Without prior training, the teacher's motivation to implement a change in their classes, regardless of whether it will lead to an improvement in the acquisition of student competencies, may be met with a reaction contrary to the change, not only at a personal level but also at an institutional level, since the necessary resources are not properly calibrated (Gorozidis & Papaioannou, 2014), in resume, how a method is implemented in detail strongly affects achievement.

Teacher training is usually regulated at different levels: (a) by a concrete and usually specific need of a given educational center, (b) by a need identified by local and/or regional institutions if they have derived educational competencies, or (c) by national and/or international regulations. There may also be needs that are regulated by institutions that coordinate associated centers, as could be the case of FIDAE in Italy, ARLEP in Spain (*Agrupación Lasaliana España—Portugal*), or AMEL in all the world (La Salle Educational Mission Assembly).

In this regard, AMEL began the process of developing a new educational and pedagogical framework at the worldwide level in all of its centers and for all educational levels in 2018. The new framework is known as the "New Learning Context" (NLC), and it is presently being implemented in schools starting at the elementary level (Herrero-Martín et al., 2020). In Spain's 104 schools, this procedure is being developed in phases (including two university centers), with a first phase in which teachers from all primary, secondary, and baccalaureate schools are being trained

in the incorporation of robotics in educational processes (Amo et al., 2021; Jurado et al., 2020), and the improvement of mathematical competence, managing in all cases the data in a private and security modes (Daniel et al., 2021).

In all the cases mentioned above, when a need for change is identified in the educational field that entails teacher training or retraining, the strategies are usually determined by the needs of the teacher, the school management, the administration, or the managers of the networks where the schools are located, with such training being mandatory and more or less scheduled (Macera, 2012). We can identify a generic factor such as the lack of resources in training centers to facilitate this task. Just is one of the main challenges and opportunities of the schools involved in Erasmus + projects, and current aspects of great interest such as educational robotics, STEAM approaches, and their relationship with the Sustainable Development Goals (Alimisis, 2019; Meletiou-Mavrotheris et al., 2020; Oliveira et al., 2021; Orcos & Aris, 2019; Poce et al., 2018; Salcedo-López & Cuevas-López, 2021; Schina et al., 2020; Shageeva et al., 2020; Tazhina et al., 2021).

To the training strategy, motivation or need of the teacher, center, regional, national, or international scope, and the possible handicaps derived from the lack of resources (including time, space, or materials) (García & Corell, 2020; García-Peñalvo et al., 2020; Gil-Fernández et al., 2021), we must now add the problem of the COVID-19 pandemic (Dietrich et al., 2020; Nissim & Simon, 2020; Toquero & Talidong, 2020). The limitations on travel and capacity are seriously damaging programs such as Erasmus + Mobility (Salcedo-López & Cuevas-López, 2021) (both for teachers, students, and partnership meetings) (García-Peñalvo, 2020, 2021), and most of the training is focusing on online or virtual modalities (Buchem et al., 2020; Gogacz & Kędzia, 2020; Koris et al., 2021; Vera et al., 2021).

Virtual training systems are allowing teachers to carry out these processes (García-Peñalvo, 2021), but they are losing an important part linked to the action of interacting with systems, devices, and even colleagues of the classic face-to-face training, something very important in STEAM approaches (Dusadee & Piriyasurawong, 2020; Mambo & Makatia Omusilibwa, 2020). The design of ubiquitous training materials and methods must allow not only training in technical aspects, perhaps the most worked, but also conceptual aspects, such as, for example, in CreaSTEAM, aspects of inclusion, diversity, gaps, and fit with the socio-cultural reality that surrounds each educational center, which is very diverse and can be rapidly changing (Delamarre et al., 2021; Gabster et al., 2020; Guerrero & Jiménez, 2019; Kumi-Yeboah et al., 2020; Sivapunniam, 2005; Stavroulia et al., 2019; Sveinbjörnsdóttir et al., 2019). From this point of view, the adaptation of training to the teacher's profile, needs, interests, or resources of the center is a priority (Ally, 2019; Galikhanov & Khasanova, 2019; Guasch et al., 2010; Hepp et al., 2015). In CreaSTEAM, we have followed a work scheme focused on the user, in our case the teacher. From an introductory online knowledge session, working groups were identified by profiles and centers to make the first approach to the needs related to the implementation of STEAM-Lab in their center. From here, in a second session, progress was established in the needs and interests, which allowed the generation of training sessions designed in the form of pills (Boice et al., 2021).

These pills, as detailed below, were designed based on a flipped classroom format, i.e., a series of videos and step-by-step tutorials were created, which were made available to teachers before a session of presentation and resolution of doubts (Campanyà et al., 2021). The objective of this format, and given the impossibility of doing the training inperson, was to provide teachers with the contents identified as fundamental in the first two sessions. This flipped format allows time for practice, and in a final one-hour session to meet the experts who will function as consultants throughout the STEAM-Lab implementation phase, resolves doubts, and even sees the real interaction with the proposed systems (García-Peñalvo et al., 2016; Sein-Echaluce et al., 2021). It is at this point, as the current phase of the project, where teachers are already in a position to define a Unit Plan of their activity with the resources they consider necessary and start the implementation in the STEAM-Lab.

3.3 Design of the Teacher Training

3.3.1 Temporal Design

As part of the intellectual output 1 of the project: Key concepts and strategies for designing and implementing a STEAM-Lab, the teacher training process discussed in this chapter was designed. This process was aimed at secondary school teachers, or equivalent in each country, with the possibility of participation of primary or secondary school teachers. The proposal was that two teachers from each school could participate in a training of around 30–40 people, counting project partners and associated schools.

The training was initially planned to be in-person and of 5 working days of duration. Because of the COVID-19 pandemic situation, the learning process was adapted and modified in order to train teachers virtually. We changed from 40 in-person hours to 20 h in virtual/online mode and 20 h of "homework" and we increased the number of participants from 14 to 32 (also including associated schools). The training was organized in three phases, as outlined in Fig. 3.1.

In the first phase, two online and synchronous sessions of four hours were defined. The main objective of this first phase was to introduce and conceptualize the STEAM-Labs in the schools. In the phase two, the focus was to do online pills, with a flipped learning methodology, about the technological tools to be used in STEAM-Labs. We selected the most voted technological tools by the teachers in phase one. The phase three took place along the second year of the project (during the implementation of the STEAM-Labs and practices in the schools) and consisted in two online sessions where the teachers had support about the pills and other contents in the process to implement their practices and projects.

A priority aspect of any STEAM training is to identify exactly what needs to be addressed. In this sense, and given the objective of our project which focuses on creating a new multidisciplinary space blending the concept of certain specific spaces,

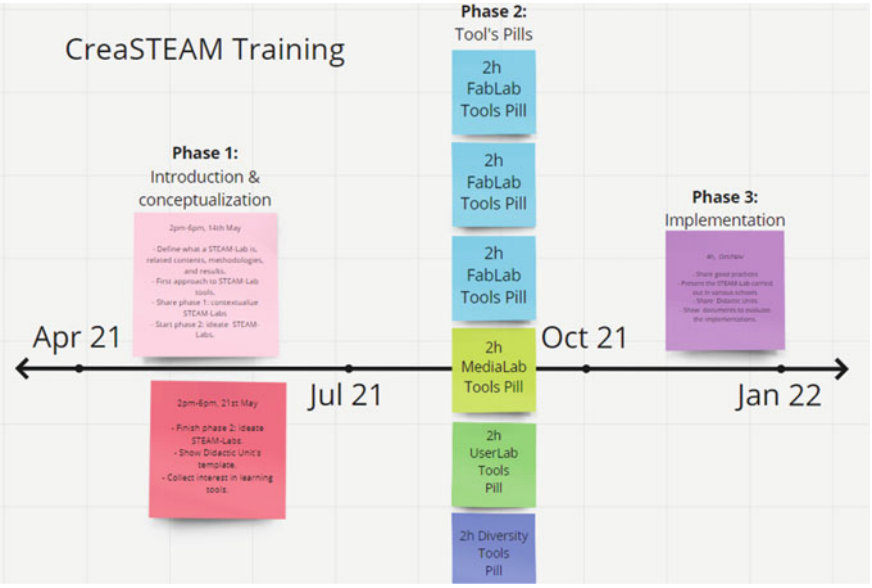

Fig. 3.1 CreaSTEAM Teacher's Training structure. https://miro.com/app/board/o9J_lJyFhuQ=/?moveToWidget=3074457357473892564&cot=14

the first step was to create a conceptual map of technologies and tools (Fig. 3.2). The map of technologies and tools was provided prior to the first training session for teachers so that they could start thinking and analyzing the particular possibilities of each center, depending on the available spaces (divide into the four main spaces identified), teachers, and necessary resources or investments.

3.3.2 Phase 1. Introduction and Conceptualization

For phase 1, two afternoon sessions were designed on two consecutive Fridays in May 2021, two sessions of 4 h, after being the most quorate options based on a survey of project partners and partner schools. The virtual workshops were designed following these steps:

- Session 1:
  - (a) Know what a STEAM-Lab is, and share the minimum requirements.
  - (b) Know the tools of a STEAM-Lab.
  - (c) Know active learning methodologies in STEAM-Lab.
  - (d) How to create inclusive spaces and attend to diversity.
    - i. Co-creation of the STEAM-Lab of each school, adapted to their reality.

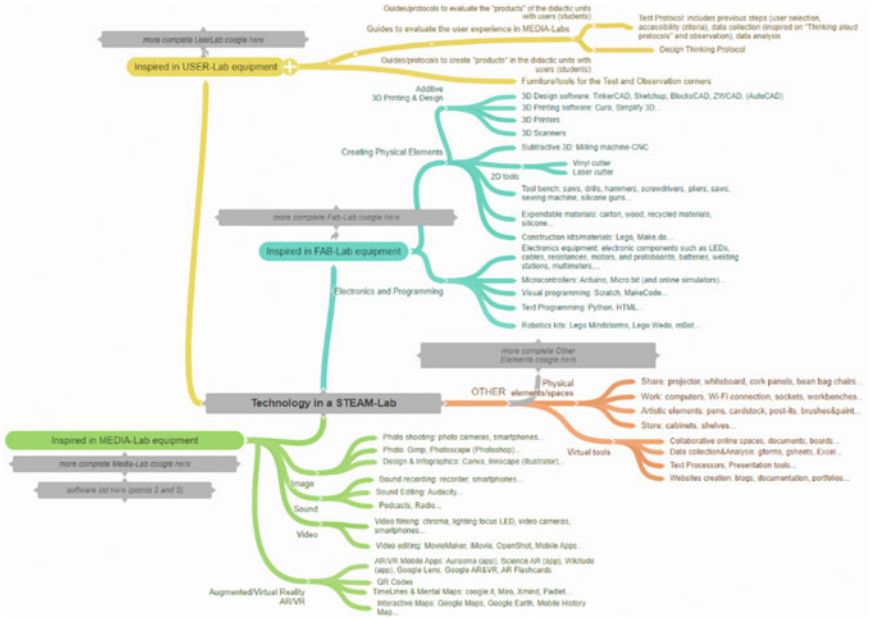

Fig. 3.2 STEAM-Lab technologies and possibilities (CreaSTEAM Project, 2020). https://coggle.it/diagram/X-Cy2_YZrx-l8zDJ/t/technology-in-a-steam-lab-star

ii. Present and share with the rest of the schools the Action Plan Templates of each STEAM-Lab.

- Session 2
  (a) Present the Templates of Teaching Units. Start a first project.
  (b) Decide/collect which tools are most interesting to learn in Phase 2.
  (c) Explain how the use of the STEAM-Lab will be evaluated.
  (d) Final Co-creation of the STEAM-Lab of each school, adapted to their reality (Finish, Ideate, Prototype, Share).

3.3.2.1 Session 1: Timing and Activities

The first session was divided into three blocks. A first set of activities to introduce the concept, and two blocks to start the creation of the STEAM-Labs action plan (Fig. 3.5). In detail, the activities carried out were as follows:

- Warm Up (5 min).
  (a) Activity using Mentimeter about the level of knowledge and practice in the topics related to STEAM-Labs (https://www.menti.com/motg98r2t9).
- Presentation (40 min).

(a) Presentation of the training program (Fig. 3.1).
(b) Icebreaker activity to introduce ourselves, "An object that defines us today". 1 min for sharing name, school, letter "STEAM", and photo of the space.

- STEAM-Labs explanation in classrooms of the s. XXI (30 min).

(a) Sharing inspiration examples for introducing the classroom to the Fab-lab of https://hackmd.io/@fablabbcn/S1jUcNvq4?type=view#MAKING-SCHOOLS-PILOT.
(b) Defining STEAM-Lab through merging options and resources of Fab-labs, Media-lab, and User-lab. We shared the philosophy of each space:
  (i) Fab-lab philosophy: Maker, creative, and service (inspiration in progress).
  (ii) Media-lab philosophy: Merge art, technology, new media, and society.
  (iii) User-lab philosophy: User testing and user-centered design.
(c) Identifying where to create the STEAM-Lab according to the school infrastructure.
  (i) Show examples of inspirational Maker spaces (fab, media, and user), both in schools or not.
  (ii) Technology tools map (Fig. 3.2).
  (iii) Example of space distribution (Fig. 3.3).
(d) Presentation about why the STEAM-Lab is necessary.
  (i) Necessities ICT profiles. Create not consume technology.
  (ii) What content? (Curriculum implementation).
  (iii) What methodology? (instruction).
  (iv) What results? (results).
    (1) See examples of interdisciplinary projects.
    (2) Show the educational project template (Unit Plans): To develop in phase 2 the unit plans.
    (3) How is it evaluated: evidences and assessment?
    (4) Integration of the teaching team and community and environment (school culture). Inclusive spaces to attend diversity.
(e) UDL (universal design for learning) and how to address the diversity gap (30 min). Presentation about how to create an inclusive space and activities based on coeducational approaches, UDL, and the concept of multiple intelligences.

- Discovering the minimum requirements of a STEAM-Lab (Fig. 3.1) (15 m).

(a) School infrastructure: Separate spaces and access to technology and equipment.
(b) Inclusion in curricula: Analyze and propose improvements in STEM subjects to include training that allows interrelation between subjects with special emphasis on creativity and a social approach.
(c) School culture: School leadership (commitment of the board of directors, management team, etc.); promote increased cooperation among all members

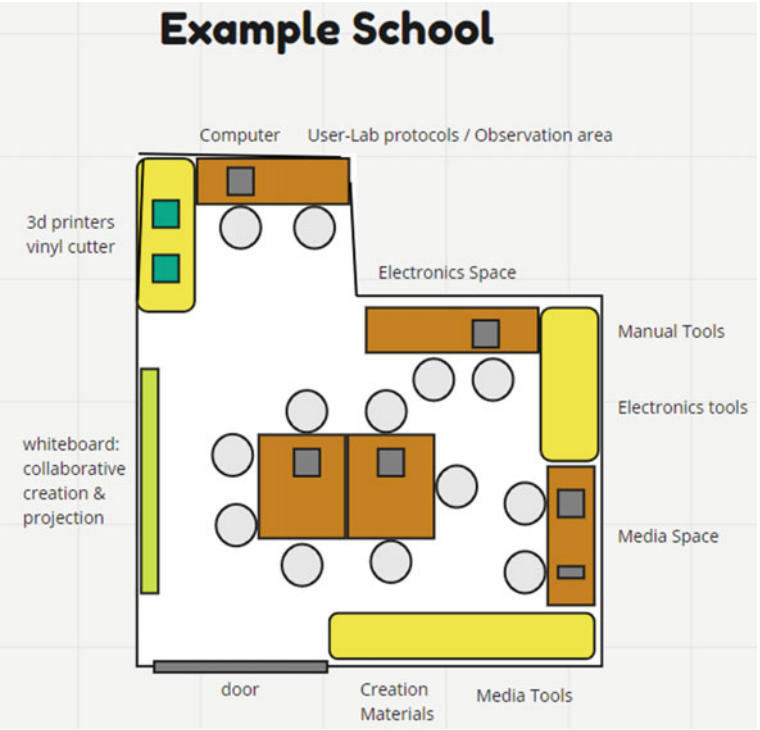

Fig. 3.3 Example of space distribution. Source: https://miro.com/app/board/o9J_lOBhHOU

of the school staff (teachers, administrative staff, etc.) and that such cooperation is conveyed toward a transversally inclusive proposal without forgetting the relationship with the students' families, local commerce, and other formative support environments such as non-formal education centers that allow the co-creation of STEAM-Lab as a communication environment for the student with all these agents.

(d) Instruction: In this sense, the following methodologies are identified as possible approaches to instruction:
   (i) Active learning.
   (ii) Project-Based learning.
   (iii) Customization of learning and inclusive environment (UDL and co-education).
   (iv) Service learning.
   (v) Collaborative learning.
   (vi) Design thinking methodologies.
   (vii) Inquiry-based learning.
   (viii) And Tinkering.

(e) Results: To obtain interdisciplinary projects that address initiatives of interest and that allow their impact to be analyzed and documented in order to share and scale learning processes and results.
(f) Inspiration and homework:
  (i) Read/search/identify books, web pages, and resources.
  (ii) Examples in phase 2 of schools with maker-fab spaces.
  (iii) Playing to design a Fab-lab in an educational environment.

After a short pause (10 min.), we started the Contextualize phase (Fig. 3.4).

- Activity in groups of schools by country (3–5 persons) in order to review together the Contextualize phase and team building (20 min).

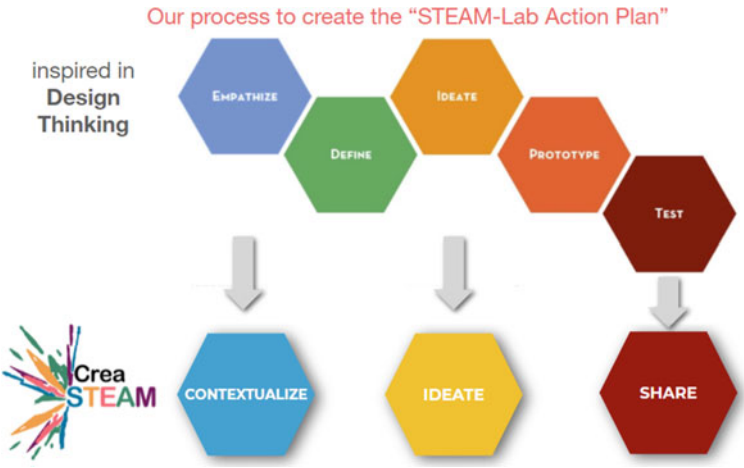

Fig. 3.4 Process to create the "STEAM-Lab Action Plan"

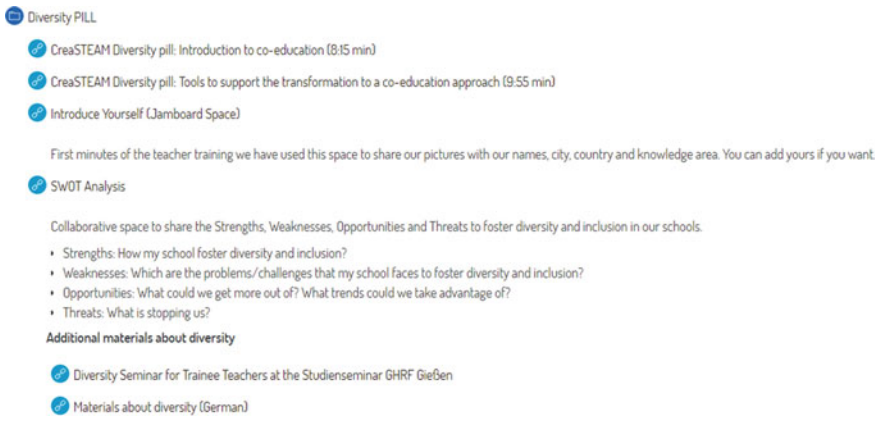

Fig. 3.5 Scheme of resources related to Diversity pill

(a) Each group work on the contextualize section of the Action Plan following the template (Jurado et al., 2021), including their context and photos of inspiring spaces for them.
(b) The groups upload their documents and work on them in a Google Drive folder.

- Contextualization pooling in the large group (15 min). A spokesperson summarizes the type of STEAM-Labs in each country, 3 min per country.
- Activity all together focused on explanation and questions of getting used to map tools, immersion in tools, and pre-creation of space (20–30 min).

(a) We show photos of various tools, and they must choose what the name is and in which group it would be classified (Fab-lab, Media-lab, or User-lab).
(b) We show recommended, most common, tools and materials from a STEAM-Lab and physical technology tools based on a tool map (Fig. 3.2).

- Presentation of phases Design Thinking and Action Plan STEAM-Lab (Fig. 3.4) (10 min).

The last block was focused on starting the ideate phase (Fig. 3.4).

- We shared examples of how to fill in the Action Plan. After that, each group was working on the ideate phase using the template (Jurado et al., 2021) (40 min).
- Short demo, explanation, and small intervention drawing STEAM-Lab space outline in MIRO (https://miro.com/) (15 min) (Fig. 3.3). In particular, we shared a canvas based on the STEAM-Lab Action Plan (https://miro.com/app/board/o9J_lOByGj4.
- Sharing ideate work and some recommendations (15 min).
- Closing (5 min). Reflection activity "What do you take away/with you from the session"?

3.3.2.2 Session 2: Timing and Activities

A week later, a new online training session was held. This session was divided into three blocks or parts, a first part to finish the ideate phase, a second part to work on the share phase, and a final part to present the action plans. The pattern of activities designed and implemented is as follows:

- Presentation of the session objectives (10 min).
- End the ideate phase of STEAM-Lab Action Plan by working in groups (same groups as that of the first session) (45 min).

(a) Introduction: Sharing doubts, ideas, and important things with the whole group.
(b) Examples of the proposal of the ecosystem of the STEAM-Lab and recommendations.

After a short phase (10 min), the second part was focused on the share and improve phase (Fig. 3.4):

- Activity in pairs of schools, from different countries at random to work on the last phase, share, and improve (40 min).

  (a) Proposals are exchanged between countries and reviewed (20 min).
  (b) Each person or school group fills out the minimum requirements checklist (Jurado et al., 2021).
  (c) They give "feedback" conclusions of another's proposal (20 min).
  (d) Each group incorporates make improvements (20 min).

Finally, the last part of the session was focused on presenting the STEAM-Lab Action Plans.

- Activity to present the action plan of some schools (20 min). A spokesperson for each school or country presents the work done during both training sessions. 5 min. per presentation.
- Survey using Mentimeter to select the tools for the second phase of the teacher training (15 min). Each participant selected three Fab-lab tools and two media-lab tools. The results were 3D Printing and design; augmented reality tools; Fab-lab programming systems such as Arduino or Micro:bit; image/video photocomposition; video recording and processing; and Scratch.
- Presentation of the Unit Plans Template (3 min) and how it will be evaluated.
- Closing activity focused on indications for the second phase of the training, including the preparation of the final STEAM-Lab Action Plans and a short reflection about the learnings during the training (10 min).

In addition, at the end of the two sessions, participants completed a satisfaction questionnaire in order to evaluate the process and the results.

3.3.3 Phase 2: Training Pills

Considering the training priorities identified by the project partners and associated schools in the phase 1, the following training pills were identified and programmed (the programming details of which are also indicated):

- September 17th, 2021:

  Diversity issues. How to address, identify, and manage diversity concepts in the class (1 h).
  3D Printing: Technologies and printers. A real-time exercise with a low-cost printer (1 h).
  Augmented reality. From CAD model to the visualization using mobile devices of 3D models using free applications (1 h).

- September 20th, 2021:

Educational Robotics with Micro:bit (1 h).
Photo Composition. Rules and tips for enhancing images and videos (1 h).
Usability. How to address basic studies related to usability and accessibility in the use of technologies (1 h).

As can be seen, the organization of the sessions was dynamic, as in one hour, the basic concepts of each topic were introduced jointly with the expert's introduction, and how to keep in contact with them for any doubts in the implementation phase (about 15–20 min), and some practical exercises were carried out and broadcast live.

Previously, all project partners, and teachers who apply for participating in the training, have had access to detailed tutorials (step by step) on how to implement each pill, along with videos detailing the process in a visual way. The scheme posted on the CreaSTEAM training platform was the following (Fig. 3.5).

Within each folder, teachers can find the presentations used in the virtual sessions of each pill, as well as the explanatory documents and tutorials, with details of procedures and utilities. Likewise, and as shown in Fig. 3.5, the explanatory videos of each pill can be found in open access on the CreaSTEAM—YouTube channel (https://www.youtube.com/channel/UCt6ZyjMo-yMCo0Bbzl5s_9A), as well as the sessions themselves that were recorded.

3.3.4 Phase 3. Implementation

Phase 3 started during a face-to-face meeting in Giessen (Germany) in October 2021. Each school presented the first approximations of STEAM-Labs. The partner schools, as well as some associated schools, presented their ideas to develop both, their STEAM-Labs as well as some practices and projects to teach or address different diversity gaps in their centers.

The implementation will continue along the 2021–2022 academic year, so the results.

3.4 Assessment of the Training

For assessing the training we have used a composed method of two approaches previously validated: The MUSIC® instrument (Jones, 1992, 2009), and the structured test based on the International Organization of Standardization (ISO) 9241–11. The MUSIC Inventory measures the five primary components of the MUSIC Model of Motivation: eMpowerment, Usefulness, Success, Interest, and Caring, and the ISO 9241 is focused to evaluate the feasibility of using the teacher training in virtual mode focusing on the usability guidelines of Effectiveness (E1), Efficiency (E2), and Satisfaction (S) (Fonseca et al., 2014, 2017).

The results of MUSIC® are in Table 3.1.

Table 3.1 MUSIC® values (based on a Likert scale of 6 levels)

Teacher training evaluation				
M	U	S	I	C
4.87	5.02	4.69	4.88	5.54

Table 3.2 Effectiveness (E1), Efficiency (E2), and Satisfaction (S) evaluated (based on a Likert scale of 6 levels)

Variables		
	Mean	*SD*
(E1-1) The material of the lecture has a good presentation	5.42	0.79
(E1-2) The structure of the sessions/exercises is appropriate	5.00	0.74
(E1-3) It is easy to manipulate/do the exercises/activities proposed	4.92	0.90
(E1-4) No problems in the visualization/manipulation of the contents	4.92	1.08
(E2-1) The number of exercises/activities are related with the time proposed	4.92	1.08
(E2-2) The number of exercises/activities proposed are related with time	4.75	1.14
(E2-3) It has been possible to solve the exercises presented	4.83	0.83
(E2-4) The application and methodology used has been stable (no crashes)	5.33	0.98
(E2-5) The interaction with the templates and systems proposed has been easy	5.00	1.04
(S1) Overall rating about the theoretical explanations	5.25	0.87
(S2) Overall rating about the practice activities	4.83	0.94
(S3) Overall rating about the usability of the contents and activities proposed	5.00	0.95
(S4) Overall rating about the digital media uses	5.00	1.04
(S5) Overall rating about the duration of the training	4.58	0.67
(S6) Overall rating about the level of knowledge and capacitation acquired	5.17	0.83

Related to the variables evaluated using the ISO 9241, the results are shown in Table 3.2.

Both for the results obtained in the evaluation of the motivation of the teachers (Table 3.1), and the usability of the system used (Table 3.2), where the minimum value of any variable is 4.69/6 (Interest of MUSIC®), the average value is 5.01/6, and the maximum value is 5.54/6 (Caring of MUSIC®), we can affirm that the design of the training has been highly satisfactory, adequate to the expectations of the teachers, and for the project.

3.5 Conclusions

The diversity gap in STEM is a well-known problem faced at all society levels. A sustainable society cannot be achieved until society is represented in the STEM

sectors that have such an impact on its development. The CreaSTEAM project proposes a new approach, the STEAM-Labs, to foster diversity and inclusion in STEM at secondary schools. The definition of this new space is a co-creation process that involves different stakeholders (teachers, educational decision-makers, and researchers). This work describes the key activity of the co-creation approach, the teachers training focused on designing and implementing the STEAM-Labs in the secondary schools involved in the project as beneficiaries or associated partners.

The training design and the resources described in the previous sections are scalable to any school in any country that wishes to implement a STEAM-Lab in its school in the future. Although the implementation of the STEAM-Labs is under development, the training lays the groundwork for starting the process.

On the other hand, noteworthy is the handicap faced throughout the training due to COVID-19 pandemic. However, according to the assessment results, it is possible to design, implement, and manage online training with teachers from different schools and social backgrounds in four different countries on topics covering technical, social, and human knowledge. In this sense, we can already consider the training and its adaptability and scalability a success, both in this and other projects.

Acknowledgements With the support of the Erasmus+ Program of the European Union in its Key Action 2 "Cooperation and Innovation for Good Practices. Strategic Partnerships for school education". Project CreaSTEAM (Co-thinking and Creation for STEAM diversity-gap reduction) (Reference number 2020-1-ES01-KA201-082601). The content of this publication does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the publication lies entirely with the authors.

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Chapter 4
Mentoring High Ability University Students: An Experience with Computer Science Undergraduates

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Abstract The new educational context poses new challenges for universities. In a situation of continuous innovation, along with the implementation of new methodologies, it is essential to ensure the diversity of the student body. This includes students at varying levels of learning ability. This research has been motivated by the need for more tools to identify students with high abilities. Only in this way, they can be provided with the appropriate attention and adjusted to their learning rhythm. The present work shows an attempt to enhance the learning experience of

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_4

all students. The starting point is our previous experience on setting up an online judge, in the context of a basic subject and in lab work, both within the Computer Science degree. As a result, a new teaching methodology was created, which allowed us to detect high-capacity students. And secondly, the higher learning rates of these students were enhanced using the new methodology. Along with the detection and intervention experience, the results of a survey, carried out with high-ability and/or high-performance students, are presented. Students share their vision of participation in this initiative of the University of Salamanca.

Keywords High-ability students · New methodologies · Inclusive education · Competency-based learning · Mentoring high ability · High capability detection · Highly capable student motivation

4.1 Introduction

The integration of Spanish universities into the European Higher Education Area (EHEA) has entailed a profound transformation of the university environment, especially in the curricula of university degrees, teaching methodologies, and evaluation processes.

The incorporation of elements such as new technologies, adaptation to a new work context, and to the new demands of students have complemented this great transformative process that the universities in our country have experienced.

The main axis of this change is the student and, therefore, the main purpose of all the innovation processes that are being implemented is to improve the students´ learning process and to correctly meet their educational needs. Teachers, in turn, are highly committed to the continuous improvement of teaching processes that allow them to provide adequate academic training and reach levels of excellence. They are dedicated to the professional training of their students while avoiding all forms of exclusion or unequal treatment.

The educational proposal for university students presented in this study respects the individuality of each student. As a starting point, we have created a platform for the student to implement different algorithms to solve a problem and automatically obtain comments on said implementation. Exercises of different difficulty levels have been proposed, from very simple to highly complex exercises.

In this sense, this study focuses on diversity, specifically, on providing high ability (AACC) and high performance (RA) students with the help they require.

This field has been widely studied in the academic field, especially in the Primary and High School stages. In fact, interesting approaches and intervention formulas can be found such as those proposed by Joseph S. Renzulli (J. S. Renzulli y S. Reis, 1997), (internationally) and Ceferino Artiles, (in Spain) who are pioneers in the practice of tutoring as an effective educational measure for the development of talent (Fernández-Molina, 2021).

From our experience at the University, university staff is notified every year, by the social affairs service (SAS), of several students who suffer from some type of disorder and require special attention. These disorders include autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADD), behavioral disorders, dyslexia, and specific language disorders (SLI). However, in more than 30 years of teaching as university professors, there has not been a single case in which teachers have been notified of the need to care for high-performance students. Does the problem lie in faculty staff who do not realize that they should care for the needs of this type of student?

Universities should make a greater effort to identify such students and to take actions that address their specific needs. It cannot be ignored that students with the greatest capabilities do have specific requirements, one of which is the need to actually learn faster. It is necessary to allow to learn with greater speed and depth than usual or required. However, the choice must theirs, because having to make a greater effort may not always lead to a more productive result. It must be the student who chooses this option, being aware that this also implies being evaluated with greater rigor, as being "forced" to do more than others could have its drawbacks (Tomlinson, 2013).

In addition, it is essential to create a pleasant, enriching, and attractive environment so that the student with high abilities does not lose the enthusiasm to learn. This environment must be implemented from the first sign of curiosity or interest in the study. To pay proper attention to people with high abilities and/or high performance, we must start with the preservation of their individuality, otherwise, no theory about high abilities or techniques or strategies of evaluation and intervention can be useful. This is the frame of the educational proposal that is presented in this study for high-ability university students.

Clearly, in order to be able to help high-capacity students, one must find them first. This is the reason why an online judge has been set up for work related to programming learning; in fact, it deals with tasks that are given to first-year students (the subject is Programing I) within the Computer Science Degree.

4.2 Theoretical Framework

Online judges are popular tools in the context of competitive programming because they can evaluate automatically the performance of code. This is done by means of input/output pairs that describe their behavior (Halim & F. Halim y S. Effendy, 2020s). Online-judge methodology connects directly with test-oriented development, which is frequently found in the enterprise world (Beck, 2003). Proof of this is the occurrence of platforms with this philosophy, in which the purpose is not just to find talent, but also to hire employees (İnce, 2021).

The main starting point is to understand that the concept of "high-capability" consists in fact of two aspects: talent and giftedness. In this sense, talented persons

may be defined as those who stand out in one or more subjects in intelligence tests, but not in all. Gifted people, on the other hand, have an ability to learn that is above the norm in all subjects. There is a common point between both types of people: they need a different type of education because their ability to learn is quite different from that of their classmates (Jiménez, 2000; Kam, 2020). Before going through the research frameworks on inclusive education focused on high abilities, it is necessary to dwell on the very concept of high abilities. This term has evolved a lot over the last few years. In initial studies it was associated with high performance, leaving aside other fundamental elements. In addition, depending on the entity that evaluated or studied the level of ability, the focus was on different aspects. Thus, for example, the World Health Organization (WHO) relies on IQ tests to define people with high abilities.

The needs of students with high abilities vary from person to person. Hence, to meet them properly, the needs of each student must be precisely identified and understood. Many papers offer definitions for these persons based on observable characteristics. However, these definitions may change depending on the difference in the application of learning regulations.

Norms tend to be unspecific and ambiguous. One could take as an example the definition in use in Castile and Leon. This description demonstrates the depth and complexity of the subject (Educacyl & de educación, 2021):

> Highly capable students are those whose learning derives from a higher-than-normal intelligence, or those who are early achievers, or also those who show unusual skills in particular aspects of learning or of personal activity. These require a unique and separate educational approach, compared to the needs of students who do not belong to this group.

The identification process is associated with an evaluation protocol carried out by the professionals from the counseling departments of educational centers. This evaluation is often distorted, since the tests carried out are not correct for the purpose. Criteria can be too restrictive; indeed, they impede most students from receiving any type of attention. This is how the educational administrations recognize people with high abilities. Beyond those criteria, students are required to have exemplary behavior, to be involved in school dynamics, to be creative, and to pass tests that prove their ability to be greater than that of their pairs.

Is it necessary to use such a process in order to detect students who are acquiring instrumental learning earlier than the rest, or whose capabilities are indeed better than those of others? From a teacher's point of view, the results they are provided with are not usually of much help. Students' intelligence quotients or statistical values are not really useful as means of providing them with any insightful information regarding the educational needs specific to each student. What teachers are really interested in is knowing how to help their students learn and develop their skills to their highest potential. A good rapport between teachers and students will enable teachers to identify students who can progress more quickly.

The beginning of the university stage puts a stop to any follow-up of a gifted person because it is not allowed to pass to universities any information that was previously known about students. All information obtained so far is lost, and teachers must,

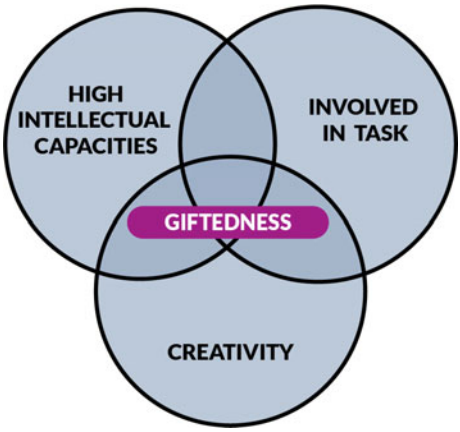

Fig. 4.1 Three features found in overachievers, according to Renzulli

once again, face the difficulties of the identification process. Thus, the main goal is again to detect high-capabilities university; in our case we try to find them out within our Computer Science studies. Furthermore, the aim of the study has been to experiment with different teaching methodologies and to analyze the results.

Students with high capabilities do not go directly to the Social Affairs service of the University. We say again, the first problem is to identify these students. To make things worse, they do not normally consider themselves exceptional. Even without reaching the highest level, there are indeed excellent students who would clearly benefit from their own path into learning, instead of following the usual methods. Once prior detection is needed. To carry out this task, models such as the three rings are especially revealing (Fig. 4.1). This is a model that has been proposed decades ago by Renzulli (Renzulli, 1977) The method makes use of the values of three features that can be found in high-capability students: intelligence, creativity, and involvement.

Renzulli gives paramount importance to one particular in particular: high intelligence. Further, he clarifies that one should look for high performance, high achievement capability rather than outstanding intelligence.

Creativity is the easiest ring to identify, since the originality and ingenuity of the student is a more striking and detectable trait. The remaining feature, which is involvement in tasks, can be measured by the interest and effort that high-capability students put into tasks, when one compares them with the rest of their classmates.

Some recent studies (Lynch, 2016) state that the detection of these high-ability students is not as hard as it seems. Teachers must keep in mind a series of features that are normally found in students of this type.

These characteristic features are related to the way these students learn. Table 4.1 summarizes five basic characteristics that appear in all of them, regardless of their personal profile or their school or academic performance.

Features of this type are the telltale for high-capability students when compared with the rest, especially in matters related to their learning rhythm, because in cases

Table 4.1 Learning characteristics of the most capable students

Feature	Precision
They learn faster …	*… on the topics that interest them*
They memorize better …	*… data of their preference*
More complex or abstract thinking …	*… than their peers*
Passion for topics of their interest …	*… at maximum concentration and exclusion of other topics*
Parallel processing of stimuli …	*… knowing what's going on around them even as they focus on a specific task*

of this type, their grades consider some aspects that differ from those used for the rest of students. Generally, they do not depend on a given grade in an exam, or on a given behavior in class, or on their notes. These five features we mention favor a deeper learning and help us adjust to the rhythm of each student. However, the performance of each high-capability student is different, and our intervention must be adapted to the individual's needs.

In this sense, high capacities are closer to the degree of development of the student (Reyero & Touron, 2003; Touron, 2013) than to other qualities or behaviors of the student.

One other aspect that must not be missed is the individuality of the student when we deal with each case. Not all students of high abilities have the same profile, hence the intervention of the teacher must adapt to each case. This makes it necessary to consider variables like cognitive profile (aptitudes), interests, learning preferences, personality, and attitude. Finally, the teacher's interventions have as their goal the enhancement of the learning experience of the student, always taking into account that each student has his own personal situation which is different from that of the other students.

Hence, both procedures and intervention methodologies must take this diversity into account.

While it is not easy to find gifted students, one can certainly find rather easily students who show high capacity and / or high performance. Of course, in these case we also must intervene. For this reason, we believe that some mechanism should be set up in order to detect students with these characteristics, and one such mechanism could well be the creation of development classrooms linked to research groups of excellence of the University of Salamanca.

4.3 Description of the Experience

As we have pointed out in previous sections, one of the first barriers to addressing the diversity of high-ability students is the lack of information from the Ministry of Education, since they cannot provide information about high-ability students

who arrive at universities. Thus, universities must look for their own identification mechanism.

Obviously, the first pitfall is that university teachers are not normally trained in "talent" detection, although they can of course perceive behaviors and results. Fortunately, several members of our team had previously been present in activities related to high-capability detection and indeed some of these activities dealt also with intervention procedures. Having acquired this experience and knowledge, we believe that this kind of training should be included in the training plan of all teachers.

The experiment described in this study has made use of several experimental groups of students; to be precise, these persons belonged to the subject scale Programación I and Programación II (which belong to the first and relatively the second semester of the "Grado en Ingeniería Informática de la Universidad de Salamanca"); to the subject called "Theoretical Informatics" taken in the second year, and finally to one last course called "Desarrollo de Aplicaciones Avanzadas" which belongs to the seventh semester (already in their final year).

The reason why first-year students (Programación I, Programación II) were selected as part of the experimental group is understandable: it was expected that any detected high-capability students could be followed in the next courses. These subjects entail a large amount of laboratory work, and they allow students to participate in the classroom, and to show creativity and involvement in the performance of tasks, which makes potentially high-capability students to be easily identified.

Taking as a starting point the theory of Lynch, and with the experience and knowledge acquired, it was possible at the end of the Programming I subject to identify several "promising" students; based on the results of student evaluation, potential high-performance students had been identified.

In our effort to enhance identification, we have made use of a new teaching innovation project called "Online-judge-based Teaching of Programming Subjects". This project is concerned with Programming I and it was initially meant to be a new methodology for the teaching of Programming. Clearly, it can also be used to identify students with high capabilities.

Online judges are popular in the context of competitive programming (the so-called Programming Olympics). They make it possible to evaluate source code files, by defining the expected output and comparing the results of running compiled code with expected results for known inputs (Bloomfield & Sotomayor, 2016). This facilitates the grading process, and at the same time it lets the user check their progress during development (from both, failed attempts and from obvious differences in results for given inputs). The importance of this approach can nowadays be seen in the industry, where test-oriented development is the norm. Another interesting aspect is the gamification of the learning process. Lately, some platforms have emerged that exploit this paradigm as a means of selecting talent, and in the context of recruiting. One such platform is called codingame (CODINGAME, 2021). Consequently, these techniques could be valuable tools for university teachers in subjects that deal with the first steps of programming. To be precise, in the context of this project we have aimed to achieve the following goals:

- To allow students to solve their doubts autonomously, by exploring different routes to reach their objectives.
- To set a precedent that invites the incorporation of this model as good practice, to be applied to subjects related with an introduction to programming in most STEM studies.
- Having an institutional online judge, which could also be useful for other activities (such as preparing for computer science Olympics, or a Hackathon).
- To detect talents, and to use the online judge as a learning tool so that students can progress at their own pace. They could also choose the desired level of difficulty, thus meeting the needs of high-capability students.

  Figure 4.2 shows the general interface of the platform (JUEZ, 2021). It can be accessed from a browser, and it allows students to traverse the series of problems created based on the contents of one of the subjects, "Programming I". By means of the web interface, students who have an account can upload their solutions for each program, which are then run in a safe virtual environment. Correctness is checked by comparing results with expected outputs, thus validating the student's code. If code is judged to be valid, the problem is marked as solved and the student is awarded a certain number of "points" that depends on the estimated difficulty of the problem, and on the number of students who solve it. Awarded points adapt dynamically, favoring students who solve harder problems.

- A closed version of the platform was deployed at the beginning of the course, to be used by the staff in charge of the subject. At this stage, it was found necessary to adapt the exercises used in teaching, which interacted with the user through the console so that they could be evaluated by means of the online judge. This implied:

Fig. 4.2 Online JUEZ platform interface for "Programming I" (Degree in Computer Science)

- Writing the problem statement within the Markdown language, possibly including other resources like images, LaTeX expressions for mathematical formulae, videos, external links, etc.
- Defining input/output pairs, some of which were to be used in the statement of the excercise, while others would be used when program execution was evaluated. The need arose too to document and define corner cases, in order to ensure the validity of solution candidates.
- Defining structured information that describes the problem (Subject to which the problem is related, keywords, degree of difficulty, limits for computational resources given to evaluation, etc.).

A rather simple example of these problems is calculating the volume of a sphere, seen from the interface available to students. This is shown in Fig. 4.3. All problems follow the same scheme concerning input and output formats, as well as several examples of inputs and their corresponding outputs.

The platform was made initially available to students enrolled in the subject with a small collection of problems. A short introduction of about then minutes was given in class; it was intended to show how the feedback from the judge can help find errors in code. An example is shown in Fig. 4.4, where the left-hand side shows an incorrect sample of code for the sphere volume (Fig. 4.3). The right-hand side shows the output produced by the (incorrect) program. In ths case, the error is due to the fact that in the expression 4/3 in C produces 1 as a result, since both numbers are integers.

The platform was offered as an optional tool, not to be graded, although tasks carried out in the lab were included in the platform (with the corresponding adaptations). Further some other examples were included; some came from previous tests and indeed a few especially complex problems were also posed. These were of course aimed at advanced students. New problems were added gradually to the

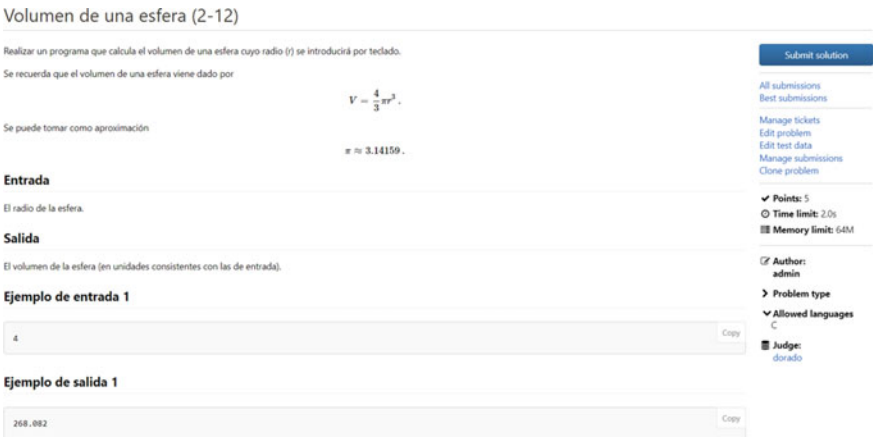

Fig. 4.3 Sample problem in JUEZ

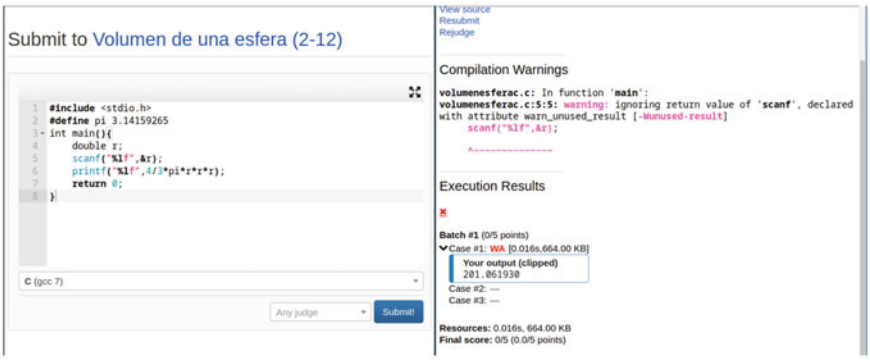

Fig. 4.4 Example of an (incorrect) attemp to solve a problem

platform during the course, trying to keep them in sync with the parts of the subject being taught at the time.

In the course of the last academic year, the online judge under development has allowed us to detect three types of clearly distinct behaviors:

- Users with little activity, who solved a maximum of 9 out of 32 possible problems. They comprise approximately 30% of cases.
- Active users, who solved a maximum of 14 out of 32 possible problems (they amounted to more than 40%).
- Very active users, who solved 31 or 32 problems. This includes two problems that were harder than the others.

The remarkable differences between users with little or mean activity can be seen in Fig. 4.5, which shows a jump between 9 and 14 solved problems. The maximum number of solved problems in the first group is 9, and the maximum for the second group is 14. The figure clearly shows both groups on the histogram. Concerning the third group, one can also perceive a jump just before the mark for 30 solved problems. These cases include solving "challenging" problems with a higher degree of abstraction. Both exercises, which can certainly be solved using the knowledge taught during the course, require a higher level of abstraction, and students are given less clues as to the way to solve them. Given their difficulty, one of the problems requires competencies that are slightly beyond those expected from first-year students, and the other one clearly diverges away from the contents being taught.

From the point of view of management, the platform allows teachers to verify both the code and the results. This makes it possible to monitor both active and very active students. Given the number of attempts and revisions of students' code, conclusions can be reached regarding their capabilities and their effort when solving problems. For instance, some of the most active users learned how to use the standard output in order to extract information related to hidden tests. This allowed us to detect one limit case that was not well documented in one of the problems; the student actually managed to solve it in this way.

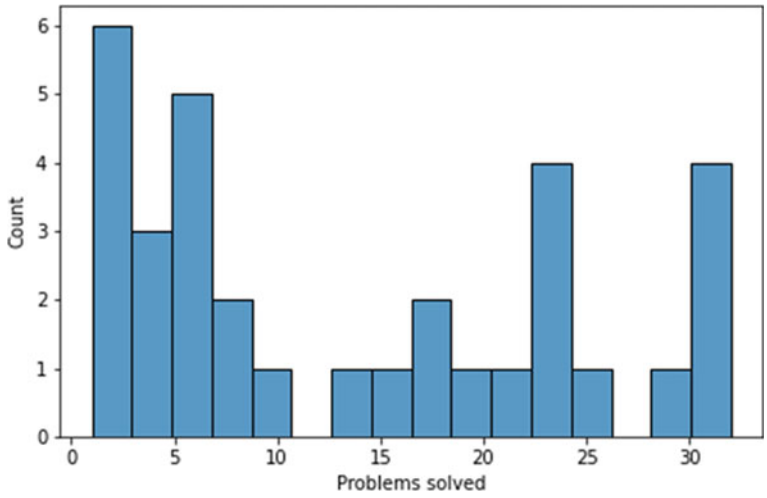

Fig. 4.5 Histogram of problems solved on the JUEZ platform

Additionally, by following the learning results of students that belong to the last group, it was possible to conclude that they really "*Learn faster*", that is, they require less time to solve the posed problems, and furthermore, they "*Are passionate about the subject that interests them*". In fact, some students did ask for harder problems. Hence, we understand the students from this group are high-capability students. They will be followed, in an effort to relate their success with their results in "Programming I". Further, they will be invited to participate in development labs, which are described below.

Once the identification work has been carried out, the intervention is launched. Individualized tutorials are the starting point in which the students are introduced to the Bioinformatics, Intelligent Computer Systems and Educational Technology Research Group (BISITE) of the University of Salamanca (USAL) (BISITE, 2021). Furthermore, they are introduced to various lines of research. The various members of the group give students the change of advancing at their own pace within the various areas.

The approach is to create a development laboratory for each of the lines of research, which in this case are multiple, specifically: artificial intelligence (AI),, deep learning (DL), Internet of things, bioinformatics, cybersecurity, educational technologies, medical technology, intelligent distributed systems, robotics, computational creativity, and social computing. At this phase, as the students were free to decide in which line of research they wanted to participate, and labs are available on next-generation mobile applications, Internet of things, and blockchain technology.

One of the most outstanding aspects of our proposal with respect to other existing proposals is that a professor who monitors students is present in each lab The teacher acts also as an academic counselor (mentoring) to avoid failure, since statistics show that high capacities are not always associated with high-performance, and we have

experienced this in development laboratories. In addition, we have proposed these student to be mentors of other classmates who have not been introduced to this project yet, because in many cases it is easier for students to understand each other.

Our experience with development labs suggests creating projects to divulgate the results from the reseach carried out in them. This program could include such activities as seminars, conferences, or scientific publications in which high-capability students can be involved. This would provide them with more academic recognition. Further, this proposal could enhance some of their capabilities, and would open a new way for future high-capability students in their pre-university stage, such as those that follow the "Bachillerato de Excelencia" offered by the "Junta de Castilla y León". This would be, at the same time a way to enhance cooperation between institutions and educational programs.

The difficulties encountered in detecting high-capability lead us to think that it will be necessary to continue observing students carefully throughout the Degree, and to perform the identification process in other subjects belonging to the upper courses, in order to give an opportunity to students who have not been identified in the first year. The academic performance of the high-ability students participating in the project could also be monitored in relation to other subjects they are taking as part of their degree. This would help analyze their interest in the activities in which they have participated and assess the potential benefits of the project.

4.4 Results

Concerning the Juez platform, data have been extracted from the platform's own statistics. This includes the number of submissions per exercise, the results of the evaluation (success, wrong result, compilation error, execution time limit, etc.). Further, an evaluation poll was carried out by the end of academic activities, before the final tests for the subject, and it was offered optionally to students who participated voluntarily. The poll was designed with single or multiple-choice items, and Liker scale results. That is, agreement to the proposed statement can go from one to five, where 1 means "total disagreement" and 5 means "total agreement".

For brevity's sake we shall only describe data related to the relationship between the results obtained in the platform and the corresponding academic performance.

Concerning the results obtained by means of the JUEZ platform for the detection of talent, we have crossed the results of JUEZ with the grades of students for "Programming I" in the case of students who solved more than one-third of the problems posed by our "online judge". The correlation is fairly good, as shown in Fig. 4.6.

On the right-hand side of the figure it is possible to see that the results for the three students who had the best marks in JUEZ practically overlap each other. They were able to solve the problems of the "challenge". Hence, JUEZ would be fit for use when detecting talent.

Additionally, both active and very active students were given the chance to get familiar with one of the development labs, where they could become involved in

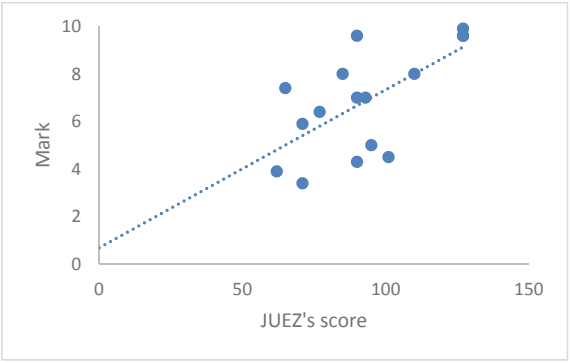

Fig. 4.6 Relationship between grades for "Programming I" and the score on the JUEZ platform

activities. All three most active students opted to participate in the labs. This makes one think about Renzulli's three rings: not only they had the creativity and capability needed to solve hard problems, but they also engage more. This makes us think that we have been truly able to detect several talented students in this year's "crop".

Finally, concerning the poll that was carried out at the end of the course, a total of 19 answers were obtained. Figures 4.7 and 4.8 show the answers in the Likert, the questions are shown too.

Up until the date on which this study concluded (May 2022), the BISITE research group had 12 students in the development laboratories, distributed among several areas. One must observe the interest shown by students on artificial intelligence The research group has been awarded a scholarship funded by the group itself. Access is rather restricted; this last academic year only three new students have joined. Permanence in the development laboratory is renewed each academic year.

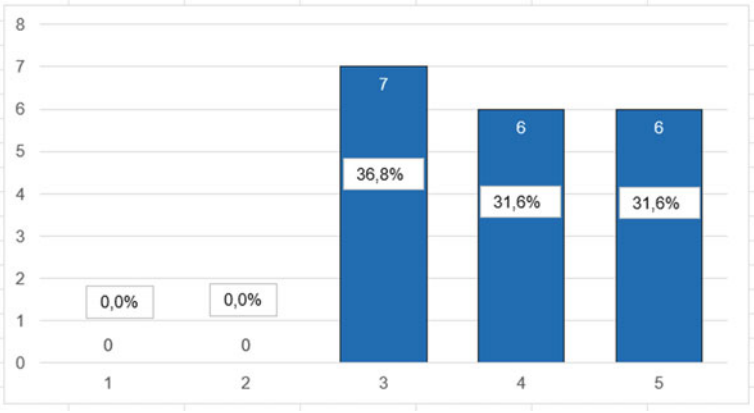

Fig. 4.7 JUEZ is easy to use (19 answers)

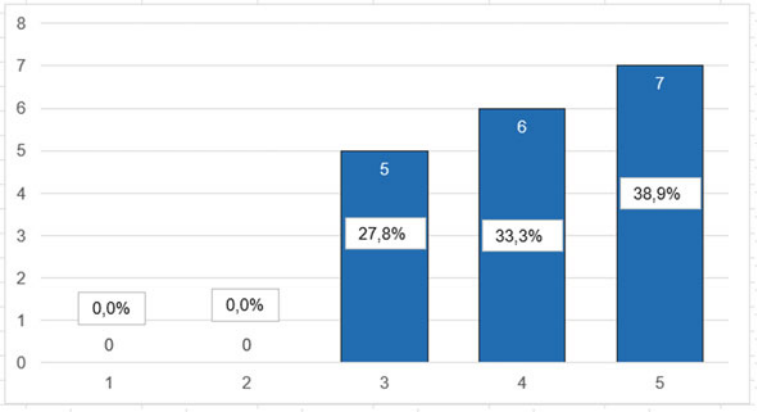

Fig. 4.8 The JUEZ experience has been positive (18 answers)

In order to measure the impact of the creation of development labs, students were offered the chance to participate in a poll that describes their point of view concerning these activities.

One of the questions is: "As a student, do you feel you agree with any of the following options?" (Fig. 4.9) Up to academic year 2020–21 the development lab comprised 9 students. In the next year, 2021–11, all six enrolled students were the same six who obtained the best in JUEZ. They identified themselves, as having high capabilities and high performance, and the remaining five as having high performance. The comparative study carried out 2020–21 (González Arrieta et al., 2021) and the one carried out in 2021–22 seem to demonstrate that the JUEZ platform is not just a learning tool for Programming, but also a tool to select talented students. It has helped reduce the amount of persons with high capabilities and low performance.

Members of the development labs were also asked whether the experience had turned out to be positive and whether they think that it should be deployed in other research areas. Their answers were mostly positive (Fig. 10).

4.5 Discussion

As stated in Organic Law for the Improvement of Educational Quality (LOMCE), "It is incumbent upon the educational management to take the measures required to identify students with high abilities, as well as to determine their needs as early as possible" (BOE., 2021). Hence, one can confirm that current by-laws in Spain state clearly the need to provide proper educational assistance to students with high capabilities. However, day-to-day activities in the context of teaching in Spain (at all levels) leave much to be desired. As stated in this paper, it is necessary to increase efforts to detect these students, in order to give them proper attention in their educational process.

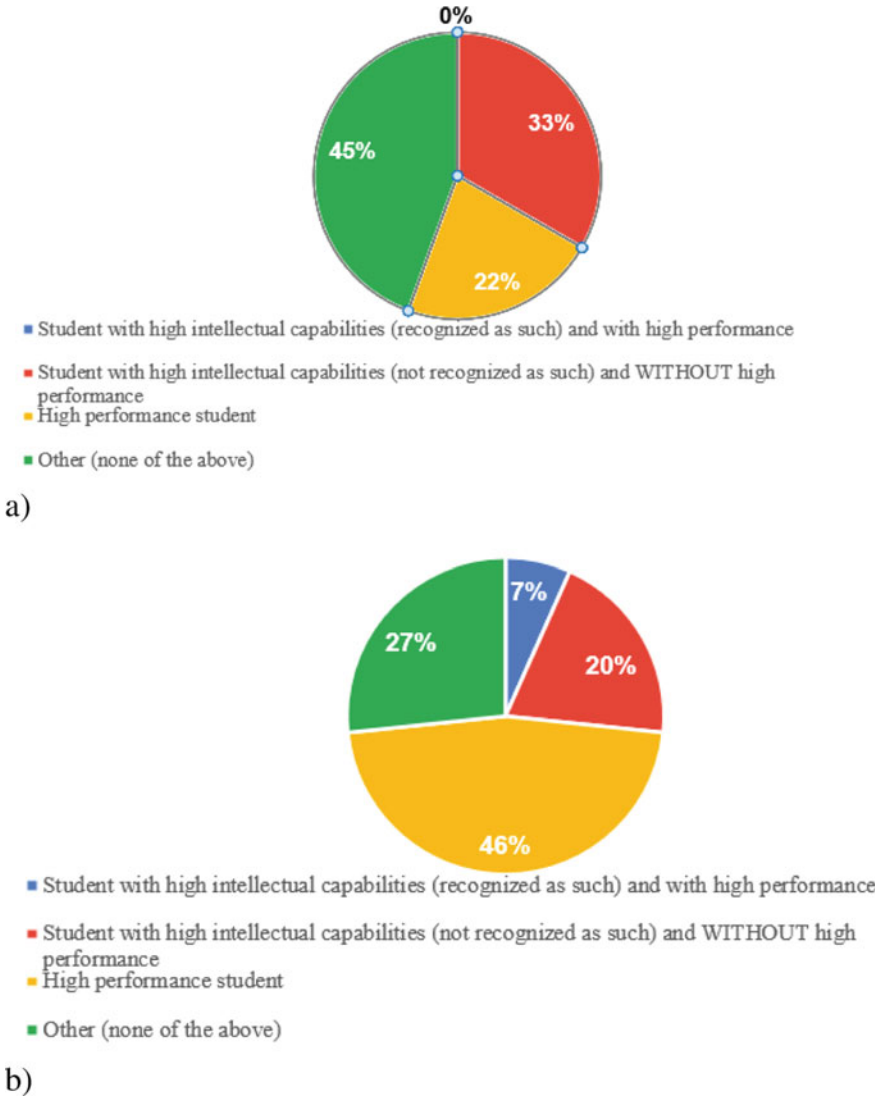

Fig. 4.9 As a student, do you feel identified with any of the following options (**a**) untill 2020–21 (**b**) untill 2021–22

Further, according to recent data offered by the "Ministerio de Educación y Formación Profesional" (PISA, 2020), out of the more than 8 million students currently involved in the Spanish educational system, only 34,113 have been identified as high-capability students.

Hence, clearly a high percentage of students with high capabilities are not receiving the attention they require. This leads to a lack of motivation, low academic

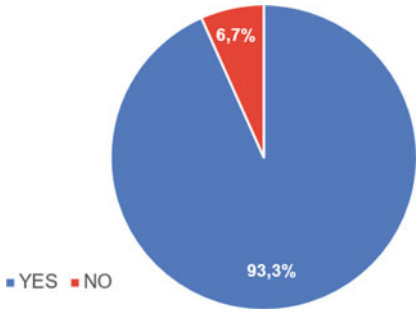

Fig. 4.10 Was this experience positive for you? Would you recommend it for other reseach?

performance, high failure rates, and finally to a large number of students who leave school or university before they become qualified. Above all, lack of attention means "wasting" or just not making proper use of the talent of persons with high intellectual capabilities, and with the potential to find other solutions to current problems.

Hence, we consider that initiatives like the one proposed here can contribute greatly, not just to the recognition of these students, but also to offering them special, customized attention. This would make it possible to integrate them in real projects with students of all types, thus enriching the work and the development of all persons involved.

Our study has been constrained by some limitations, such as time; only nine students have benefited from it. It would be very interesting to obtain more data that would allow us to learn about the reality of those students, and their evolution over the course of programs such as ours.

Hence our initiative will grow and expand in order to benefit a larger number of students in our university. Indeed, we started the program with just one student, but their number has increased with each passing academic year.

4.6 Conclusions

Concerning the use of the online judge, one of the most important aspects of the tool is the impact on students (as seen from the results of the poll). Further, it helps grade the students within the subject (as seen from the correlation between judge results and grade statistics. There is also an important aspect when used to solve doubts (shown by the interaction between staff and students during the experience). And finally, the judge helps detect talents.

The main difficulty for students is learning to work with input/output pairs, although this in fact is possibly an advantage since test-oriented development is widely used in industry.

A further line of research is the application of the judge to other subjects.

With the experience we have acquired, and once we have analyzed data obtained from our surveys, we believe that the detection mechanisms of high ability and/or

high-performance students should be improved, especially in the university environment. Furthermore, there is much confusion caused by myths that surround high-capability students, including the perceptions that high-ability students lack emotional intelligence or are unable to adapt to the social environment. This only makes it more difficult to identify high-ability students.

Along with the implementation of this task, it would be very helpful to set up plans, funded by the educational administration, in order to facilitate high-ability and high-performance students' access to university, such as those who participate in different programs, such as the baccalaureate of excellence or those who finish their studies in a professional conservatory. Additional forms of helping high-capability students could include specific university programs or providing a quota of university places for this group.

Likewise, we consider that it would be desirable for these students to be included in the development laboratories of research groups of excellence, if possible, with scholarships from the Ministry of Education and Vocational Training, so that all students receive the same opportunities.

Moreover, as evidenced by the survey data, the experience of development laboratories has been very well received, hence it could be extended to other departments or educational levels. It would be positive if certain students, in turn, became mentors for other students from lower courses. Undoubtedly, this would be an extra motivation and another formula for academic recognition, which would act as an incentive.

Therefore, it is necessary to give continuity to the assistance given to students with high capacities and/or high performance during their university training and to facilitate university access to students identified as having high capacities.

Acknowledgements We would like to thank the University of Salamanca for the call for aid in innovation and teaching improvement projects. In granting us help for the proposal "Innovating in higher education with students of high capacities" (Project Code: ID2020/097), USAL made this proposal possible. Also, for enabling the project "Online Judge-Based Teaching in Programming Subjects" (Project Code: ID2021/079), which has contributed to the further development of this project.

Undoubtedly, we would like to express our gratefulness to the research group of the University of Salamanca, BISITE, which has enabled us to carry out the initiative described in this article.

Last but by no means least, we would like to appreciate all the teachers from the subjects "Programming I" and "Programming II" for their contribution.

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Chapter 5
Challenge-Based Learning: Inter-University Implementation in Animal Breeding

Noelia Ibáñez Escriche, Cristina Casto Rebollo, Nora Formoso-Rafferty, Oscar González Recio, and Joaquim Casellas Vidal

Abstract The challenge-based learning (CBL) is a powerful tool in which the student is at the center of the learning process through experiential learning. This new learning framework has been shown especially useful for improving academic results in abstract subjects such as Animal Breeding. This subject is characterized by strong theoretical and abstract content focused on genetically-based animal selection. The aim of this chapter was to show the results of an inter-university implementation of a CBL experience using information and communication technologies (ICTs) in Animal Breeding. The challenge for the students was to manage a dairy herd genetic breeding program with real management and economic constraints using the DCBSP online software. The results showed a good progression of the performance throughout the challenge which supports CBL as a useful tool to develop critical thinking through the practical application of theoretical concepts. Additionally, the implementation surveys of inter-university CBL in the Animal Breeding course on DCBSP evidenced a high satisfaction and a strong effect on the participation, and the motivation of the students for all Universities. The Inter-University CBL is an engaging tool for teaching and creates an environment in which students can construct knowledge of abstract subjects. The results of this project are transferable to many

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_5

other subjects with possible drawbacks such as the theoretical content, the number of students, or the impossibility of the real challenge.

Keywords Challenge-based learning · Animal breeding and genetics · Information and communication technologies · Inter-University

5.1 Introduction

The aim of the Animal Breeding subject is to train professionals oriented to acquire specific competencies related to the design, organization, and application of breeding schemes (Piedrafita, 2015). Achieving this objective requires the combination of a wide range of knowledge from different areas. The subject of Animal Breeding is characterized by strong theoretical and abstract content focused on genetically based animal selection. Its application to both domestic and wild species involves a moderate knowledge of statistics, matrix algebra, and probability combined with classical and contemporary genetic theory, and applied concepts of animal production.

Animal breeding attempts to address the selective breeding of domestic (and wild) animals with the intention of improving desirable and heritable qualities in the next generations. Lectures, practical classes, and simple simulations are the methods usually applied in Animal Breeding Courses. Although these methods have shown to work reasonably well, they have certain limitations. On one hand, lectures can lead to student passivity, difficulty in favoring the immediate assimilation of the contents, and the limitation of their critical and creative thinking (Atkins & Brow, 1988; Beard & Hartley, 1984). On the other hand, solving exercises and problems helps to clarify and consolidate the knowledge acquired. However, the emphasis is on understanding the contents of a text and calculating a numerical solution to the problems instead of solving real cases. In contrast, challenge-based learning (CBL) makes students come up with specific solutions to a complex problem based on the real world (Blank, 1997; Fletcher, 2011; Jou et al., 2010; Martí, 2010). CBL is a helpful learning tool to internalize the concepts of a subject, put them into practice, and reflect on how the decisions made can influence the results obtained. However, the implementation of a real case in Animal Breeding is conditioned by the fact that the genetic change in animal populations is a medium- to long-term process due to animal selection throughout generations (Alfonso, 2014).

Menn (1993), who evaluated the impact of different instructional media on students' retention of the subject matter, found that they remembered only 10% of what they read, 20% of what they heard, 30% of visuals related to what they are hearing, 50% if they watch someone doing something while explaining it, but almost 90% if they did the job themselves, even if it was only a simulation. In other words, properly designed and implemented computer simulation could improve education (Zhou et al., 2009). Computer simulations have been progressively used in education mainly for analyzing and learning Animal Breeding principles and practices

(Buchanan et al., 1988; Carlson, 1985). There are reports from the late 1970s and early 1980s on their successful implementation in university methods (Carlson, 1985; McGilliard & Edlund, 1979) because of their advantages in terms of time, flexibility, and cost (Medrano et al., 2010). Computer simulations can accelerate lifespan and farming practices to reduce several years of real selection into an academic quarter, or even shorter periods of time. Likewise, simulation processes can be repeated and moved backward or forward to evaluate alternative decision frameworks, without additional penalties and loss of the opportunities inherent in selection decisions on real livestock populations. All these options are provided at no economic cost, except for relatively small surcharges related to computational services. Nevertheless, these simulation programs need to quickly address advances in farming practices, genetic evaluation, and selection programs to provide users with a realistic and formative experience. Otherwise, they simply become a useless picture of the recent past.

To the best of our knowledge, the Dairy Cattle Breeding Simulation Program (DCBSP) is the only simulation program that has mimicked genetic issues in the dairy industry during the last 70 years or more. This program was developed by Lon D. McGilliard (Department of Dairy Science, Michigan State University, Michigan, MI, USA) in the late 1950s within a single trait context (Medrano et al., 2010) and later upgraded to multi-trait by McGilliard & Edlund (McGilliard & Edlund, 1979). These first versions relied on contemporary comparison indices and moved to the best linear unbiased prediction at the beginning of the twentieth century (Medrano et al., 2010). The DCBSP has now implemented genomic evaluation procedures and economic constraints. This software makes it possible for a student to directly interact with his own virtual herd, increasing his motivation and leading to better interaction and information flow between teachers and students. The DCBSP can thus reinforce lectures in both concurrent demonstrations of the principles being taught and individual practical exercises. In a recent study, Blasco (Blasco, 2021) cited some books that combine the theory of quantitative genetics (Caballero, 2019; Falconer & MacKay, 1996; Lynch & Walsh, 1998) and others that deal with the classical evaluation method of Animal Breeding (Gutiérrez, 2010; Mrode, 2014). However, it is difficult to find a text that addresses the basis of quantitative genetics, the classical method of Animal Breeding, together with recent advances like genomic selection. Through simulations such as DCBSP it is intended to cover this practical need for students to understand the fundamental concepts of Animal Breeding for their training, professional development, and proper interpretation of the results of other programs.

Active methods such as CBL require a great deal of involvement on the part of both teachers and students. The teacher must support the students with knowledge and practical advice to help their learning through the process. This role does not solve the challenge, it simply guides the students (Beijaard et al., 2000). At the same time, students must work actively with their peers and teachers to identify the handicaps, ask relevant questions, and take actions to solve the challenge (Rådberg et al., 2020). However, for a successful CLB the student's intrinsic motivation must be encouraged (Baeten et al., 2012). The *Sprint* is a popular practice carried out in successful companies to motivate employees (Lang, 2017). It aims to generate healthy

competition while allowing employees to internalize new knowledge. In a classroom competition between students can be very beneficial and a powerful tool for engaging students (Willis et al., 2017). By exploiting their competitive and resourceful natures, these sprints provide an incentive to advance technical skills. As Willis (Gavin et al., 2017) pointed out, often, competitions serve to increase diversity and inclusiveness in problem-solving, inviting a broad range of viewpoints and participation, in addition to developing critical thinking and comprehensive learning, intended to enhance student motivation through two strategies:

(1) Assess the evolution of the improvement programs carried out by the student.
(2) Organize an Inter-University "sprint" where students compete not only with the students in their class but also with different universities and degree courses.

The implementation of the second strategy aims to boost student motivation by allowing them to compete on a weekly basis with those from other universities and courses. Inter-university application allows the challenge to be transferred to many more students and to properly assess its effectiveness in learning.

5.2 Context

This work analyzed the learning process and the satisfaction degree of students to acquire abstract concepts in the first year of implementation of a CBL. This CBL was based on the simulation of an Animal Breeding program using the online software DCBSP. It was developed in an inter-University environment with the participation of students from the Degree in Genetics at the Universitat Autònoma de Barcelona (UAB; Bellaterra, Barcelona, Spain), in the Degree in Agricultural Engineering and Science of the Polytechnic University of Madrid (UPM; Madrid, Spain), and Degree in Agri-Food and Rural Environment Engineering in the Intensification of Agricultural Farms at the Universitat Politècnica de València (UPV; València, Spain).

5.3 Description

The DCBSP is a software written in Fortran90 programming language that operates on DOS-Windows, MacOS, and Linux operating systems. This program complies with the GNU Fortran Compiler v.4.7 or later (available in https://gcc.gnu.org/fortran/). This program simulates a realistic framework with a large number of dairy cattle herds and provides one of them to each student (i.e., cows with connected pedigree through artificial insemination, historical records of milk yield and related traits, and progeny). The genome of all the animals is simulated based on 29 chromosome pairs with 3,000 biallelic genetic markers per chromosome, some of them being causal mutations generating the genetic background for milk yield, percentage fat and protein production, and somatic cell count. These four production traits are

generated and registered in each lactation for all cows involved in the simulation process. These phenotypes combine both genetic and environmental sources of variation (i.e., cow effect, herd-year effect, and residual effect) and are the starting point for genetic evaluation processes after accounting for pedigree data. Breeding values are predicted once a (virtual) year by multivariate best linear unbiased prediction. Genomic prediction can also be applied in some (or all) animals if desired; the program applies a two-step genomic prediction approach with different accuracies depending on the target population (i.e., heifers/cows, yearling bulls, or founder bulls).

All the information regarding production traits, reproductive outputs, and genetic or genomic breeding values of individuals or herds is provided by the program as plain text documents. In this context, the users have all the necessary information to take effective selection decisions on their animals, after defining an overall selection goal for all the participants. Decisions focus on the selection or culling of replacement heifers and cows, and the choice of both new and older bulls for artificial insemination of active females in the herd. Reports from DCBSP to each participant and their selection decisions to DCBSP are delivered through a web page interface with password-protected access. Each time the DCBSP is run, all the herds evolve through a virtual year, and reproductive events such as being in heat, artificial insemination, gestation, calving, and lactation take place in a realistic timetable in the virtual framework. There are two main ways of genetically improving dairy herds: the first one (short-term) focuses on culling decisions taken on those animals with the worst predicted breeding values. Their removal from the breeding herd quickly impacts on the average breeding value of the remaining animals. The average genetic change is provided to all the participants in the next release of herd reports. The second one (mid-term) focuses on genetic improvements achieved by decisions on artificial insemination since they are the starting point of the genetic background of the future calves, of which the females will be available to join the herd when adults.

For this study, the DCBSP v.5.16 was run in the UAB computing facilities and generated a starting population of 140 dairy herds with 40 cows per herd and ~ 50 male and female calves per herd, 25 bulls for artificial insemination, together with all previous production records and pedigree data. The web page interface used to communicate DCBSP with the participants was developed by Casellas (Baeten et al., 2012) and loaded into a private internet server with password-protected access to all participants. Participants from the UAB, UPM, and UPV took part in the challenge from different locations and a Chat Page was created to facilitate communications among the participants. The herds not finally assigned to any participant were randomly managed by the DCBSP itself. All the herds were evolved for six virtual years of selection in six weeks in the first semester of the 2018/19 academic year. The multi-round approach gave the participants several chances to evaluate themselves and the consequences of their decisions, and they could change their selection criteria from one round to the other if they so desired. The web page interface was open from Monday to Friday to upload culling and artificial insemination decisions, and closed at weekends, when the DCBSP merged all data and evolved herds and animals along a virtual year. At the end, the program carried out a new genetic evaluation of the

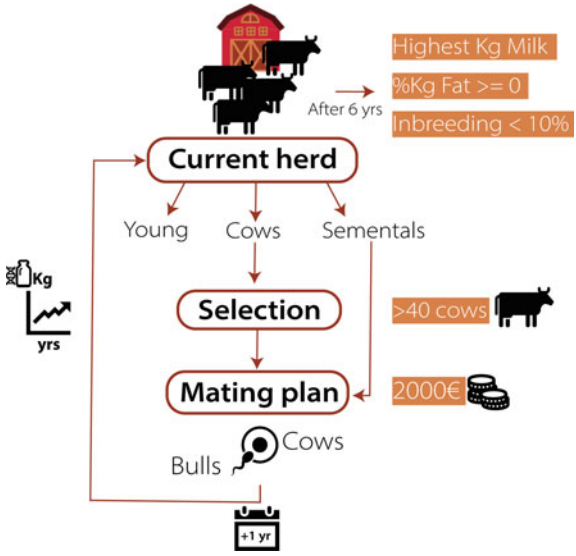

Fig. 5.1 Workflow of the challenge-based learning by the Dairy Cattle Breeding Simulation Program

whole dairy population and generated a new set of reports that were made available to all the participants. The students were given a 2-h introductory lecture and practical exercises on the DCBSP, genetic principles related to breeding and selection, and the main objectives and evaluation criteria prior to starting the selection challenge. They also had access to the DCBSP User Manual software and a description of the aims of the challenge (Fig. 5.1), the timetable, and the final scoring system.

Genetic indexes are a way to measure the animal's ability to transmit its genes to the next generation. They have been part of the livestock industry for more than 25 years. They may be production, conformational, or a combination of both, and any other heritable trait that can be measured. It is essential to understand that a genetic index does not measure an animal's physical trait (technically known as phenotype, e.g., coat color, height, or milk production) that reflects its genotype. This distinguishing is relevant, as many cows can produce high quantities of milk, although their high production might be more a function of their management regime than their genotype. Consequently, a genetic index provides the best possible estimation of an animal's ability to transmit a trait, ignoring the effects of its management regime and other environmental factors. Predicted Transmission Capacity (PTA) is perhaps the most applied index and forms the basis for many other indexes used worldwide. It is mainly a genetic index of production: namely, milk components (in kg), fat (in kg and percentage), and protein (in kg and percentage) are computed for males and females.

The final target was to obtain the maximum average genetic merit for milk yield (kg), and the final score obtained at the end of this challenge was proportional to the increase obtained (Fig. 5.1). However, two additional conditions were applied for the average breeding value for the fat percentage of milk and average herd inbreeding. If

at least one of both was not satisfied, they failed the challenge whatever the genetic milk yield progress. At the end of the six-round selection process, the in-herd average breeding value for fat percentage had to be equal to or greater than in the starting round, although no additional score was given for increasing this average. This was a challenging restriction because of the negative genetic correlation between milk yield and fat percentage. In other words, cows with positive breeding values for milk yield tended to have negative breeding values for fat percentage, and vice versa. The students thus had to deal with this negative correlation during the six rounds of selection, aiming to increase milk yield without excessively reducing fat percentage, although a maximum average inbreeding of 10% was allowed. This forced them to review their previous information on inbreeding, which occurs when crossing two related individuals. All the pedigree back to the grandparents was detailed for all animals so that they were able to avoid mating between relatives to control inbreeding. If not, inbreed animals could be culled before being selected as replacement heifers. To sum up, the main target and additional conditions were designed to foster self-learning of genetic concepts such as breeding values, genetic correlation, inbreeding and relationship, and resemblance between relatives, among others.

Although DCBSP can manage herds of all sizes up to 99 cows, the challenge is restricted to a minimum of 40 cows per herd in each round. This limit was laid down because selection success is evaluated in terms of average breeding values, and a minimum size was required to obtain relevant comparable average estimates. Participants could increase herd size above 40 animals at any time during the selection rounds, although they were warned about the advantages (i.e., a larger number of selection candidates because of an increase in the number of offspring) and disadvantages (i.e., reduction in selection intensity and average budget per cow; see below) linked to this strategy. Once again, this restriction was useful to introduce relevant theoretical concepts on genetics in livestock populations and selection programs.

The last restriction referred to the economy. Each participant had a within-round €2,000 closed budget for artificial insemination and genotyping (excess budget did not accumulate from one round to the next). They had to select a sire for each cow or heifer from a list of 10 available sires defined by the DCBSP administrator, whose cost depended on breeding values and reliability. They were also able to allocate part of the budget to genotype females and use this additional data for genomic evaluation. This had a direct impact on the reliability of its predicted breeding values and those of its close relatives. This was generally an optimum breeding ground to discuss the different possibilities and the best way to obtain the maximum benefit from the available budget. Can we use cheap bulls with low reliable predicted breeding values and invest in cow/heifer genotyping? Is it better to spend money on reliable and expensive sires, if this prevented genotyping of a relevant number of productive females? Previous restrictions were used to make participants face relevant questions on animal breeding and genetics.

Students were encouraged to take part in computer simulations to improve their initiative. The learning initiative was specifically designed to promote competition among the students to encourage their interest and involvement. A fair framework was provided in which everybody had an equal chance to succeed, with equal resources

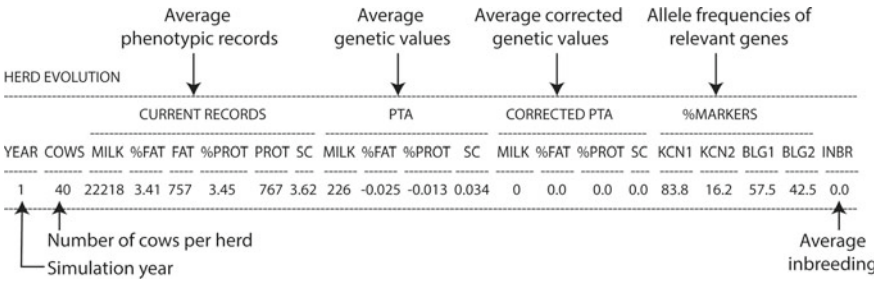

Fig. 5.2 Summary of the main herd features in the virtual years (MILK: milk production; %FAT: fat percentage; AT: fat content; %PROT: protein percentage PROT: protein content; SC: Somatic cells count; PTA: Predicted Transmitting Ability; KCN: mayor gene for κ-casein 1 and 2; BLG: mayor gene for β-lactoglobuline 1 and 2; INBR: inbreeding)

and all the necessary information. In this context, all the herds were simulated on the same genetic basis and algorithms. The small losses in the herds at the beginning of the simulation were subtracted from the final selection trends in the sixth round of selection to prevent biases due to slight random advantages or disadvantages at the beginning of the simulation (i.e., the genetic progress obtained was evaluated as the difference between the latest and the starting round instead of the gross value in the last round). Both the economic budget and artificial insemination sires were the same for all the participants in the teach round. Although random processes could not be completely removed from the simulation, the equal distribution of the resources guaranteed that differences between herds were mainly due to the participants' decisions. All the detailed information on an individual's own herd was always available as well as the overall performance of the other competitors' herds (Fig. 5.2).

The results for each virtual year and herd were stored for subsequent analysis of the effect on the acquisition of breeding concepts and the evolution of the challenge. For this, the evolution of milk output and fat percentage over the years was evaluated and possible effects such as university or sex were tested through a multiple linear regression model. The effect of these factors was by a Fisher's test setting the significance level at 5% ($\alpha = 0.05$). At the end of the Animal Breeding subject at all three Universities a student survey consisting of thirteen questions on a Google Form was carried out (Table 5.1) to assess student satisfaction with the implementation of the CBL, the ICT toll used, the overall learning method and their perception of their learning achievements. The differences between the universities were also tested for the survey questions and a weekly tutorial was organized in each university to support students on the challenge and obtain their feedback on the CBL.

Table 5.1 Survey of the students who performed the challenge

Variable Rated	Questions	Score
Challenge information	The objectives were clearly defined	1–5
	The start and end date of the simulation was clearly specified	1–5
	The evaluation system was properly indicated	1–5
User guide	Explains how the program works	1–5
	Explains the content of the output tables	1–5
	Indicates where the relevant information is shown	1–5
CBL satisfaction	How useful do you think it has been?	1–5
	Did you find it complicated?	1–5
	Why was it complicated?	Short answer
	Overall satisfaction	1–5
	Satisfaction with the program handling	1–5
Acceptance	Would you like to repeat it?	1–5
	Would you get better results?	1–5

5.4 Results

The Inter-University Challenge proposed provided weekly results of the herd performance for each participant student. This allowed assessing not only the overall result at the end of the challenge if not also the progression and the impact of the decisions applied. Figure 5.3 shows the mean of the genetic merit of milk production (kg) and milk fat content (%) achieved per week (year of virtual selection) by each University. These results correspond to herds managed by 104 students: 12 from UPV, 32 from UPM, and 60 from UAB. The trends of the genetic merit showed a good progression of students' performance for all Universities according to the challenge's aims (Increase milk production with a fat content greater than zero). Nevertheless, there were differences among universities in challenge success rates and also in evolutionary patterns. The UPM was the University with the smallest performance for milk production at the end of the challenge (Fig. 5.4) being significantly different from UAB (p-value = 0.03). The results of the UPV were intermediate between UAB and UPM, but his evolutionary pattern was remarkably different. In the first two weeks the main strategy of the UPV students was to increase milk production without considering milk fat content. Although in these two weeks the UPV results of milk production were considerably better than the UPM and UAB, there was a drastic drop in fat content (Fig. 5.4) which could lead to failing the challenge with negative fat content values. However, UPV students recognized their failure in this first strategy and took appropriate action in the following virtual years.

No differences were found in the success of the challenge as regards students' gender. To test their learning achievements, the success obtained in the first two weeks was also tested with respect to the last two weeks. The results showed relevant differences between both periods (p-value < 0.01). This result shows that the learning

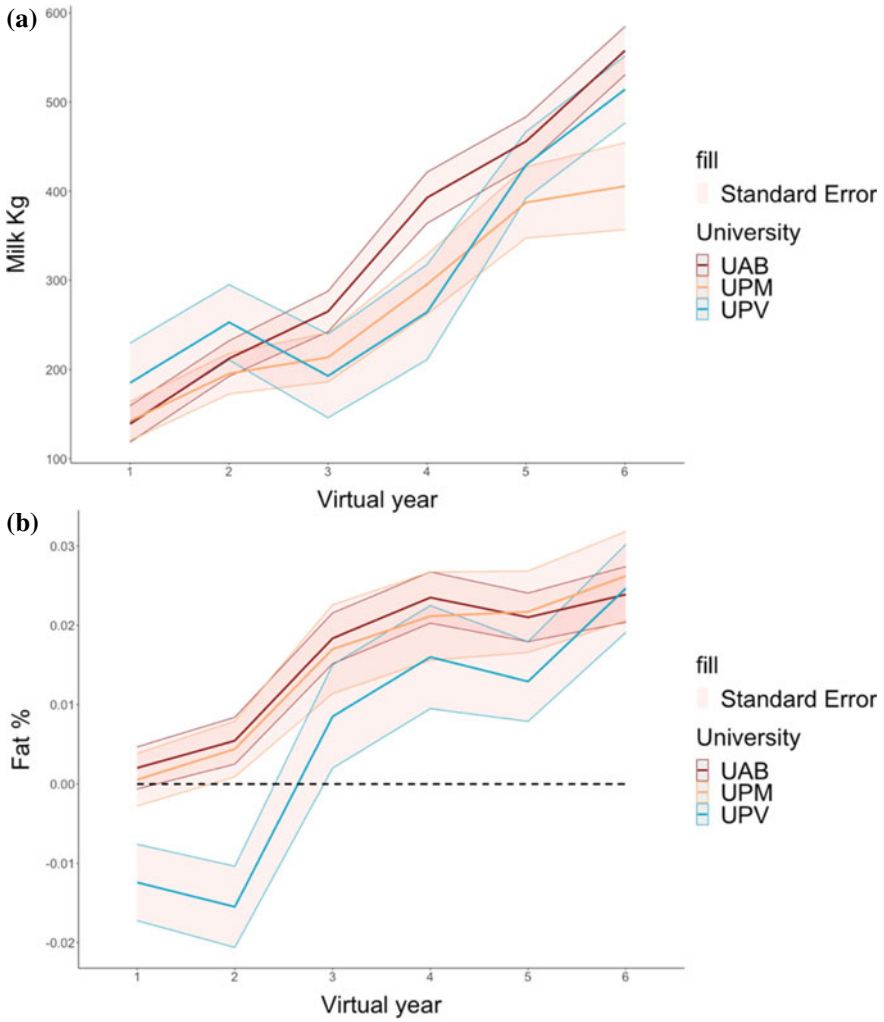

Fig. 5.3 Genetic merit trends and the standard error for milk production in kilograms (Milk Kg) (**a**) and milk fat content in % (Fat %) (**b**) by virtual year and University (UAB: Universitat Autònoma de Barcelona; UPM: Universidad Politécnica de Madrid; UPV: Universitat Politècnica de València). The dashed horizontal line indicates the threshold of the mean breeding value of milk fat content to overcome in the last virtual year to achieve the challenge

and the application of Animal Breeding and Genetics concepts improved the success through the challenge. Most students managed to improve the genetic merit for milk production in their virtual farms while keeping milk fat content above zero. They chose different strategies in sire selection and cow culling, which reflects their critical thinking to achieve the main goal of the CBL. Those who did not achieve the goal or the pre-established conditions (positive fat content and inbreeding lower than

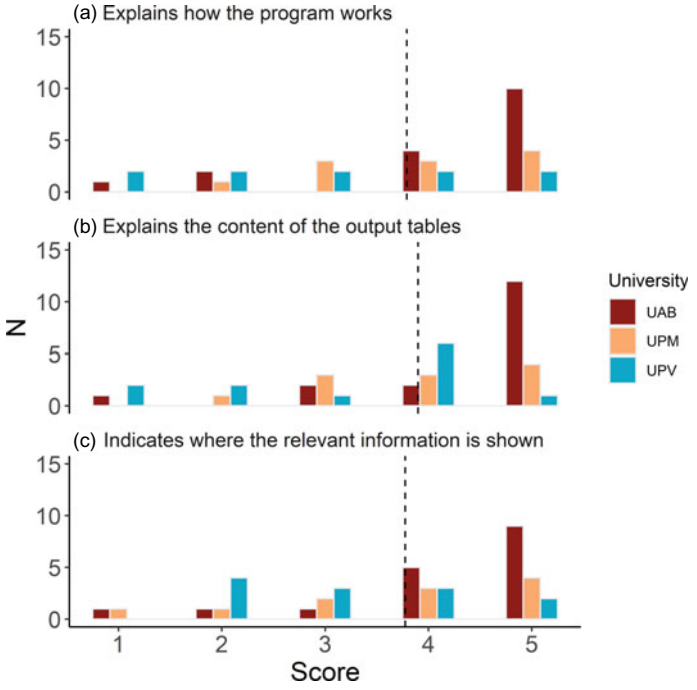

Fig. 5.4 Satisfaction rating of the user manual created for the program handling. The dotted dashed line indicates the average score obtained for Universities (UAB: Universitat Autònoma de Barcelona; UPM: Universidad Politécnica de Madrid; UPV: Universitat Politècnica de València)

10%) were allowed to submit a report explaining their difficulties and the strategy they would use in case they needed to repeat the CBL. The reports showed a good understating of their mistakes and their newly proposed strategies reflected a good level of learning.

The herds' evolution clearly showed that the students successfully met the challenge and indicated a positive learning process. However, these results cannot be used to assess either the implementation of the challenge, the students' motivation, or their satisfaction with this type of learning. An online survey was used to evaluate all these aspects. They completed a total of 41 surveys (12 UPV, 11 UPM, and 18 UAB). Figure 5.4 shows their perception of the DCBSP software, User Manual, and the document specifying the objectives, timetable, and evaluation system on which the CBL was based. This evaluation of the quality of the written instructions is very important, particularly in the success of the CBL, since it provides of easily readable extensive details (Dunham et al., 2020). The average score assigned was 3.9 out of 5 for the explanation of the table contents, and 3.8 out of 5 for the explanation of how the program works and the instructions for carrying out the CBL. These ratings, close to 4 out of 5, indicate good overall satisfaction with the user manual and indicate room for improvement.

Figure 5.5 shows the results obtained for the assessment of the explanation of the key elements required for the CBL, such as aims, start and end dates, and evaluation system. These were positively evaluated, with a score of more than 4 out of 5, although the explanation of the CBL's objectives was not rated as positively as expected (3.7 out of 5). The determining factor was probably the difficulty of associating the subject concepts with the CBL, since the challenge started at the beginning of the subject of Animal Breeding and Genetics. In future CBLs we will place more emphasis on this section and on the possible difficulties at the beginning of the subject. However, some authors suggest that it may indeed act as a catalyst to help them overcome any conceptual obstacles they face throughout their learning (Muller et al., 2008; Ohlsson, 2011).

Figure 5.6 shows the survey results for the questions related to satisfaction with challenge-based learning on DCBSP software. Most of the students found the challenge useful for their learning, with an average score of 4 out of 5. The difficulty of the challenge got a mean score of 3.4 out of five. Most of the students said that the greatest difficulty was at the beginning before they had fully understood some concepts. This was in line with the score obtained in the explanation of the objectives (Fig. 5.5). No

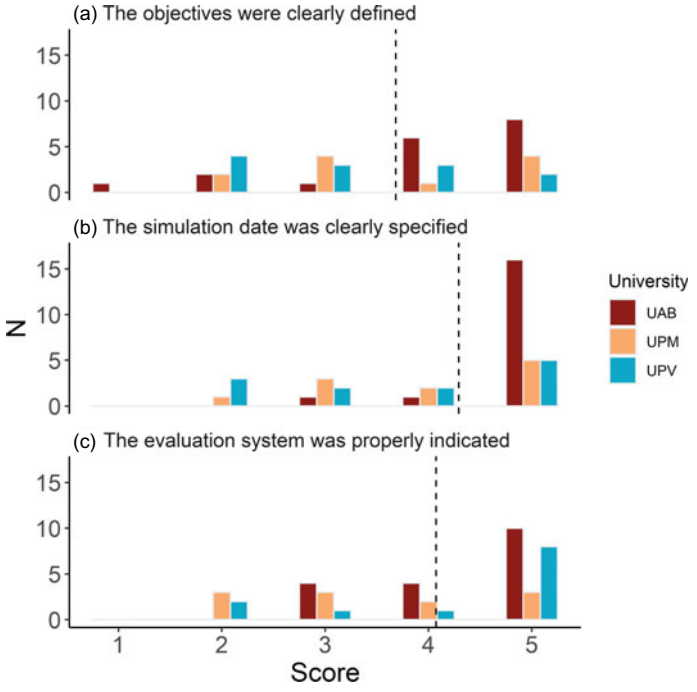

Fig. 5.5 Satisfaction score of the of the information on objectives (**a**), dates for starting and ending (**b**) and evaluation procedure (**c**). The dashed line indicates the mean obtained for all Universities (UAB: Universitat Autònoma de Barcelona; UPM: Universidad Politécnica de Madrid; UPV: Universitat Politècnica de València)

differences were found between the Universities. The initial difficulty and how it was later overcome was reflected by their progressively improving results. Our results agree with the Muller (2008) and Ohlsson (2011) studies, which reported the positive effect of the difficulties in the learning process. Difficulties and confusion are significant in the learning process, especially in areas that require an understanding of complex concepts (Lodge et al., 2018). Additionally, considerable prior knowledge or the challenge being too easy could be detrimental to challenge attainment by not considering possible errors in their approach (Arguel et al., 2019).

Figure 5.7 shows the percentage of students per University who would participate in the challenge again. The highest percentage was obtained at the UPV with 100%, although there were no significant differences among the other universities. This high percentage of students who would like to repeat the challenge indicates a good acceptance and motivation for this type of learning. On the other hand, most of the students considered that they would improve their results, which supports our CBL implementation as an effective learning framework. The desire to repeat the challenge and the expectation of obtaining better results imply that the students have thought about their mistakes. These results are in line with other studies that also reported

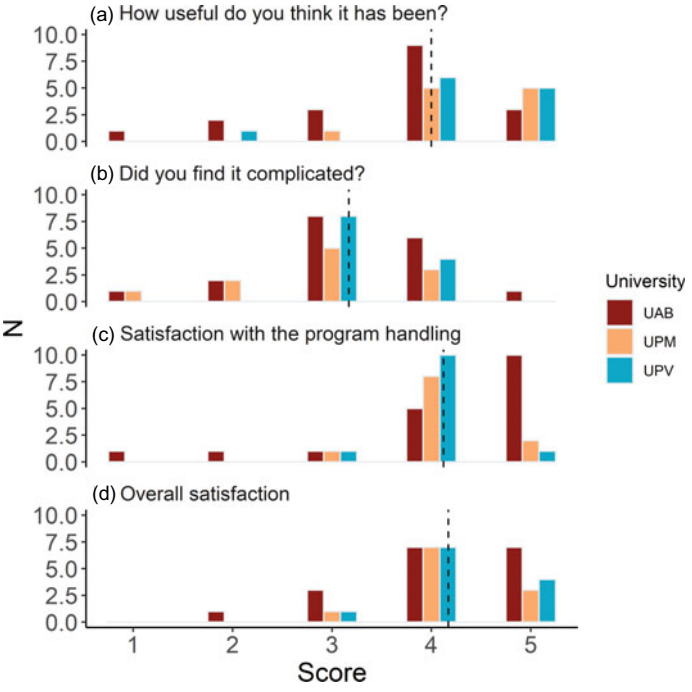

Fig. 5.6 Satisfaction score of the explanation of the challenge and the DCBSP software handling. The dashed-dotted line indicates the mean obtained for all Universities (UAB: Universitat Autònoma de Barcelona; UPM: Universidad Politécnica de Madrid; UPV: Universitat Politècnica de València)

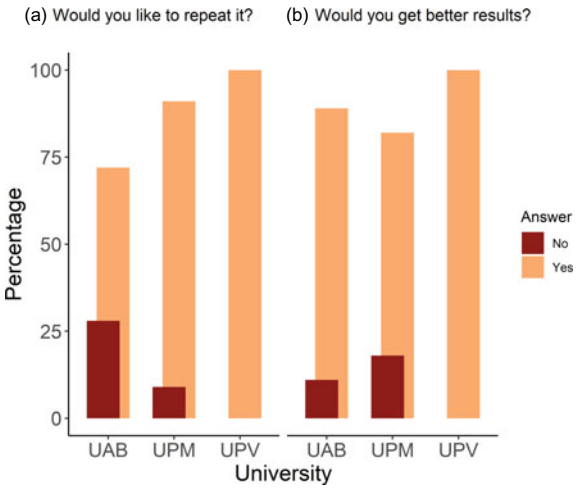

Fig. 5.7 Percentage of yes and no answers for the questions related to the acceptance and achievement of the challenge at each University (UAB: Universitat Autònoma de Barcelona; UPM: Universidad Politécnica de Madrid; UPV: Universitat Politècnica de València)

on the effectiveness of CBL for reaching learning outcomes (Herreid, 2013, Bonney, 2015, Krain, 2016).

The students' improved motivation was one of the improvements highlighted by the teaching staff. This perception was based both on the student surveys and on the feedback obtained during weekly tutorials. This is important because the enhanced motivation was one of our aims to implement the CBL in the subject of Animal Breeding and Genetics. It is a key factor in any learning method, especially in active learning, and is positively related to performance (Williams, 2005).

5.5 Conclusions

This work shows that the implementation of an inter-university CBL in the Animal Breeding using the DCBSP online software improves the acquisition of abstract concepts. The challenge strongly influenced the student participation and motivation, as well as their critical thinking through the practical application of the theoretical concepts. Our results suggest that CBL is an engaging tool for teaching and creates an environment in which students can construct knowledge based on making a decision under a real-world context.

The inter-university coordination was key to the success of this educational project. It not only improved student motivation but also gave them a more complete assessment of the results obtained. However, there are some important aspects to improve that may have influenced the challenge and should be considered. The initial explanation of the program is essential to make it easier to use, as well as to clearly indicate the objectives. In addition, the interactive User Manual with an emphasis on the most relevant information helped their performance.

The results of this project are transferable to many other subjects in different universities and showed that possible drawbacks such as a subject's theoretical content, student numbers, or the impossibility of the real challenge lasting longer than the subject can be overcome by coordination between universities and the application of appropriate ICT tools.

Acknowledgements We are grateful to the *Instituto de Ciencias de la Educación of the Universidad Politécnica de València* for funding the Educational Innovation Project PIME/20-21/203.

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Chapter 6
The Use of New Technologies Applied to the Project-Based Learning Method in an International Context: VII Virtual Intensive Programme on the Future of Banking and Finance

Pedro Fernández Sánchez and Elizabeth Frank

Abstract The use of new technologies applied to teaching has led to a qualitative leap in education due to the pandemic caused by COVID-19. This chapter describes the experience of converting an intensive program that had been celebrated in person since 2014, into an online event. Thus, through a project-based learning process, students of different nationalities were able to expand their knowledge related to ethics and finance, as well as other skillsets, such as autonomous and collaborative work, working in a multicultural environment, or the development of technological and language skills. All this was possible thanks to recent developments in software and applications that allow students and teachers to collaborate simultaneously while being separated by hundreds of kilometers in different European cities.

Keywords Autonomous work · Cooperative work · Online meeting · Internationalization · Project-based learning · New technologies

6.1 Introduction

The outbreak of the pandemic and the subsequent global shutdown in March 2020 affected all areas of our lives. Just a week before the planned on-site meeting of the Intensive Programme (IP) in March 2020 on the Future of Banking and Finance (FBaF), the event had to be canceled. And this, although it had previously been successfully celebrated for six editions, allowed University students and professors of up to six different nationalities to participate.

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_6

Almost a year later, when the effects of the pandemic were beginning to subside, but restrictions remained, a decision was taken to build on what had been learned during the confinement and to transform the IP into a virtual event. This chapter aims to explain how emerging learning technologies were applied to further develop a project-based learning program in a multicultural environment.

This chapter will first explain how the idea of launching the IP came about, and then outline the objectives of the program. Thirdly, it will explain how the IP has been organized in a virtual way after six face-to-face editions, followed by the role played by new technologies in converting it into a virtual event. Finally, the results obtained from the surveys carried out by the participants will be presented.

6.2 The IP: Origin and Evolution

From the mid-1980s until the beginning of the twenty-first century, the world economy was characterized by the stability of the main macroeconomic variables. This is the reason why this period, in which growing investment spurred by the low level of risk and uncertainty, is referred to as the Great Moderation. This term, coined by Stock and Watson (2003), was popularized by Ben S. Bernanke, Governor of the US Federal Reserve, at a conference in 2004 (Bernanke, 2004).

Despite the economic boom, signs were accumulating warning of a possible financial crisis, though initially everything indicated that it would take place in the so-called emerging economies (Martín Aceña & Pons Brías, 2011). The lack of regulation of financial institutions in the US, together with the drop-in interest rates in the early 2000s, had favored the creation of a real estate bubble. In parallel, financial institutions had been securitizing mortgage loans and consumer credit into marketable securities. As Martín Aceña and Pons point out, the system rested on the existence of cheap credit and increasing house prices (Martín Aceña & Pons Brías, 2011). This clearly unstable equilibrium broke down when house prices began to plummet, leading to an increase in default payments. Thus began the subprime crisis which eventually led to the so-called Great Recession. Originating in the US, it shook all economies with an unparalleled intensity since the Great Depression of 1929.

Following these events, Petra Hogendoorn-Schweighofer from Inholland University of Applied Sciences (The Netherlands) felt the urge to transmit to students that a great deal more had gone wrong than the traditional business aspects usually studied by economists and economic historians. Specifically in ethics, the excessive risks taken by market players and questionable behavior that crossed ethical lines played a decisive role in the outbreak of the Great Recession. In this context, the development of an Intensive Programme on Ethics and Banking was proposed, in which different European Universities would participate and discuss these issues. The first meeting took place in Rotterdam (The Netherlands) in 2014, with Madrid (Spain), Ghent (Belgium), Katowice (Poland), Prague (Czech Republic) and Zaragoza (Spain) in

2019 as the venues for the following years. In March 2020, the IP was to be held in The Hague (The Netherlands), but the outbreak of the pandemic and the subsequent global shutdown meant that the event had to be canceled.

European universities, aware of the important added value that this program represented for students, began to work on an alternative to the physical meeting. After six editions, it had been found that participants developed a series of transversal competencies, which coincided with those that employers nowadays most request (Martínez Clares & González Morga, 2019). The development of tools for distance learning, which took place during the lockdown, and the experience gained during those months, would help to develop a new virtual intensive program. The idea was to create an experience for students in which they associate the idea of learning with those of participation, information search and autonomous and cooperative work for subsequent discussion (Fernández Batanero, 2004). All of this is combined with the use of new technologies.

Under these premises, a working group was formed by professors from the Inholland University of Applied Sciences (The Netherlands), University College Ghent (Belgium), University of Economics in Katowice (Poland), University of Heilbronn (Germany), University of Administration and Finance Prague (Czech Republic), University of Zaragoza (Spain) and University CEU San Pablo, Madrid (Spain). The objective: to celebrate an IP in a pandemic world where travel was not possible.

It should be noted that the IP has always been a flexible program, adapting to the economic situation at any given time. Once the Great Recession was over, it was given a new orientation, linking the future of banking and finance with sustainable development. Brundtland's definition states that sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment & Development, 1987). Sustainable development calls for growth without significant deterioration of the environment and depletion of natural resources on which human well-being depends. It also calls for quality of life, fairness and equity, participation and partnership. Therefore, the three pillars of sustainability are the social, the environmental and the economic pillars. In this sense, "Sustainability transition in finance is seen as the result of existing regimes which open up as a consequence of external shocks (climate change, energy transition, low carbon economy) and simultaneously bottom-up innovations and new financial initiatives" (Ryszawska, 2016).

6.3 Collaborative Work in a Multicultural Environment: The Project-Based Learning Method

As explained, the IP involves the collaboration of students from across Europe. At the end of the program, these students must write a policy document on decision-making within financial institutions. The focus lies on how to work toward sustainable financial institutions incorporating the rapid technological changes on the chosen

topic. Also, students should articulate factors for success when working with people from differing cultures and train intercultural sensitivity by reflecting on intercultural collaboration.

To facilitate the work and to ensure broad coverage of such a generic topic such as the future of banking and finance, students and professors were divided into six topic groups that cooperated throughout the program. These topic groups, six in total, were the following:

Topic 1—"Corporate Rating versus Sovereign Rating": this topic focuses on the areas of business rating and sovereign rating, independence of credit rating agencies and regulation of credit rating agencies in the European Union and in the world.

Topic 2—"Taxation, financial regulation, sustainable fiscal and monetary policy": although taxes were not the root cause of the 2008 financial crisis, some aspects of tax policy might have contributed to increased risk-taking of banks and indebtedness of households and businesses, leading them to adopt wrong economic decisions. This situation could have contributed to excessive demand in the housing market and boosting prices. This development, combined with tax avoidance and irresponsible lending practices, could have paved the way for a speculative bubble and following instability.

Topic 3—"Corporate Governance": The Lehman Brothers collapse and an improper securitization of the US subprime mortgages triggered a major financial crisis in 2008. This financial crisis resulted in general screening of financial institutions' capacities to introduce mechanisms to prevent the situations that had resulted in the crisis were to take place again. In this topic group, students have the task to investigate two Banks from their respective countries and review information provided on Corporate Governance issues. The aim is to identify which banks seem to do better in terms of transparency regarding directors' compensation schemes, gender equality policies, composition of the board of directors, etc.

Topic 4—"Evolution of Banking 2030 and beyond: the influence of Fintech": this topic centers on the development of FinTech that refers to the use of new technologies in the financial services industry to improve operational and customer engagement capabilities by leveraging analytics, data management and digital functions (Deloitte, 2016). Mostly, they are rather small and innovative digital companies that provide user-friendly banking services. In general, Fintech's have two unique selling points: better use of data and frictionless customer experience. Above that, they have a totally different business model than banks and are not subject to the same regulatory scrutiny as the highly regulated banking sector.

Topic 5—"Alternative ways of financing for SMEs": financing SMEs has long been the monopoly of banks. The financial crisis of 2007–8 has led to changes in capital adequacy standards. These have made it financially less attractive for traditional banks to finance these companies. Alternative ways of funding are being developed across Europe and elsewhere in the world. Researching which alternatives are being developed and the business models that are being used by the key players is the subject of this topic.

Topic 6—"Socially Responsible Investment (SRI)/Sustainable Developments in Banking and Finance": in the current financial environment, alternative investments

have found new ways to deliver high returns and at the same time incorporate environmental, social and governance (ESG) aspects. The socially responsible investment market is growing rapidly. Questions revolving around the differences in the SRI marketplaces between countries, the role of financial institutions offering sustainable products, international requirements and legal frameworks for SRI investing and finally the topic of "greenwashing" practices are subjects of this topic group. Selecting two products of one or two banks from the respective countries allows for a comparative analysis in terms of ESG.

Students and professors from seven European Universities participated in the virtual meeting in 2020, which was organized by Inholland University of Applied Sciences (The Netherlands), University CEU San Pablo (Spain), University of Finance and Administration Prague (Czech Republic), University of Zaragoza (Spain), Ghent University College (Belgium), Heilbronn University of Applied Sciences (Germany) and Katowice University of Economics (Poland).

The ultimate objectives of the program are to encourage autonomous and collaborative work in a multicultural environment and to use new technologies. This allows students and teachers from different European cities to work together, without the need to be physically in the same place. The aim is to stimulate students to think critically about the future of Finance. Project-based learning is used for this purpose. Through a complex and meaningful project that is developed in several phases, the aim is for participants to acquire a variety of skills by promoting autonomous and collaborative work (García-Varcálcel Muñoz-Repiso & Basilotta Gómez-Pablos, 2017).

6.4 How is the Program Organized?

The conversion of the IP into a virtual meeting introduced important new features with respect to previous face-to-face editions. As will be explained in the following section, the development of new IT tools applied to the educational field allowed the introduction of these new features.

The IP has two distinct stages: one phase, called Pre-IP, which takes place in the weeks prior to the intensive program. The other takes place during the days of the meeting, in this case virtual. What does each stage consist of and what is the aim of each one of them?

6.4.1 Pre IP-Phase

This stage takes place between January 25th and March 14th, 2021. In this stage, the students are divided into international groups according to the topic groups as explained above. They must carry out a scientific project. By posing a hypothesis and using scientific language, the aim is to encourage students to work independently and

cooperatively. Throughout the weeks in which this phase takes place, the participants must answer a series of questions individually, paying special attention to the situation in their countries of origin. They are hereby guided by two to three topic teachers. At the same time, they must progress in the elaboration of a joint academic paper responding to the previously established hypothesis.

All the documentation needed for this phase is available in the IP Student Handbook. To facilitate this work, the teachers who lead the topic group set up the deadlines for the individual submission and establish the drafts of the final paper. New technological tools are used for this purpose, which allow the members of the topic to be in contact with each other, to upload documents and to work together. In the following section, the role of these tools, which are Microsoft MS Teams and WhatsApp, in the pre-IP phase will be developed in more depth.

This preparatory phase of the virtual IP is drastically different from the previous pre-IP phase that took place when the IP was an on-site event. In the pre-IP of the virtual meeting, the students now do what was previously done in the preparatory phase and during the physical meeting. The use of new, virtual tools as mentioned earlier has made this possible.

At the end of this phase, the members of each topic group must have produced a document and a presentation, following the Pecha Kucha format, in which they explain the objective of their work and the main conclusions obtained to their colleagues from the other topics. This presentation will play a very important role in the virtual meeting. The objective is to present the outcomes of each international group paper to the audience in a concise and effective manner. In finalizing the presentation, each topic team must engage in future collaboration with other topics, thus they will have to provide some ideas about the possibilities of cooperation with the topic indicated. The presentation should not include what each topic did but rather tell the audience about the findings and stimulate the subsequent discussion.

In addition, during the pre-IP phase the students participate in a workshop on intercultural skills, given by an expert from Inholland University of Applied Sciences. The aim is to let them discover the depth of international work, and for students to understand that there are cultural differences that must be considered when working in an international team. The aim is for students to realize and consider these differences as an enriching element rather than an obstacle.

6.4.2 The Virtual IP-Event

During the IP days, the focus is on in-depth study, comparative analysis, application and presentation of results between the different topics. The students must study the way the six topics are interrelated and influence each other. The topics are bundled into 3 groups to focus on during the three IP days. Based on the video presentation each topic group must make during the Pre IP phase and topic paper, each topic group is asked to study how topics are related and how they influence each other. In this section, guiding questions are formulated based on two linked topics.

(a) Group 1 merges the previous topic groups 1 "Business rating and state (sovereign) rating" and topic group 2 "Taxation and fiscal regulation". The addendum paper of this merger should reflect how the two topics are interrelated, more specifically regarding aspects like What are the relationships between business rating, corporate tax rates, accounting and tax base and tax havens? How are the ratings related to the pension systems? How can the fiscal regulation and taxation regimes affect the business ratings and the state (sovereign) ratings? What policies can we observe in this regard?
(b) Group 2 mergers the previous topic groups "Corporate Governance" and "Socially Responsible Investment (SRI)/Sustainable Developments in Banking and Finance". During the IP Week, students from topic 3 (Corporate Governance) and topic 6 (SRI) work together to discuss several themes that are interrelated between these topics. Students will rely on the preparatory work they have done. The objective of the common group work is to review the previously investigated banks in terms of ESG performance. Students are asked to proceed with an in-depth analysis of the sustainability reports of the different national banks. Based on a self-developed matrix comprising ESG criteria such as environment, climate change, greenhouse gases, energy efficiency, air and water pollution, diversity, human rights, gender equality, health care and safety, bonus policies and executive compensations, anti-corruption, independence, structure, and composition of the board of directors, shareholders' rights, and transparency among others.
(c) Group 3 merges the previous topic groups "The influence of Fintech" and "Financing SMEs". Questions that could be answered related to topics 4 and 5 are What role can technological developments and Fintech companies play in fostering access to financing for SMEs? Does Fintech lead to new business models in finance? Can new business models in general be enabled through Fintech?

In the in-depth study, special lectures and coaching are provided. Guest lecturers from different financial and governmental institutions deliver lectures. During these three days, students are requested to study the presentations of each topic group and to see how they influence the analysis of their own topic group. Students will write an addendum to their international topic paper, especially focused on the questions that have been explained. If students find further interesting details related to their own topic from the other related groups, they may also elaborate on these.

This phase of the IP was completely redesigned following the outbreak of the pandemic. In the face-to-face meetings before 2020, students did not have to work on this type of addendum. The aim of introducing such an addendum was to enhance the collaborative work around which the program is designed and to add a new perspective.

Once again, new IT tools have made this online meeting possible. MS Teams became the key element of this virtual meeting by providing all the necessary tools to work and meet across great distances. This also enables, as will be explained below, the possibility of carrying out a series of group activities without the need for participants to reunite in the same place.

6.5 New Technologies Applied to the Virtual IP

As previously explained, the main protagonists of the virtual IP are the new technologies, which have made it possible to develop this international educational event in times of a pandemic. Following the same scheme developed in the previous section, we will differentiate between the two phases into which the IP is divided.

6.5.1 Preparatory Phase: WhatsApp and MS Teams

Each of the six topic groups into which the IP is organized has students from seven different institutions in six different European countries. At the beginning of the preparatory phase, the members of each topic do not yet know each other. For this purpose, the teachers acting as guides, or so-called topic teachers, set up a WhatsApp group. Students, and topic teachers, must introduce themselves by writing a short text explaining what they study, where they are from and what their hobbies are. They must upload a photo and a short video describing what a day in their life is like and show a favorite place in their hometown. Although WhatsApp is not the main communication tool, it is very useful, because everyone has this application installed on their mobile phones. The speed of responding is faster than with email or the MS Teams messaging system. In fact, it is used by teachers to send important notifications to the team or by students when they have a question that needs to be answered relatively quickly (see Fig. 6.1).

However, the tool around which the IP truly revolves is Microsoft Teams, which allows for meetings, file sharing and joint work on documents. It should not be forgotten that during this preliminary stage the students must produce a scientific paper. For this purpose, the team at Inholland University of Applied Sciences created six group sections in MS Teams, one for each topic (Fig. 6.2).

The topic teachers established a schedule where the dates of the virtual meetings were published by topic, and with the deadlines for the individual questions (autonomous work) and the final paper (collaborative work). Specifically, and in a schematic way, these were the activities planned in the pre-IP phase:

(a) FIRST WEEK: first meeting and zoom game via MS Teams. The aim is for students to introduce themselves, to determine the objectives of the topic and, using a zoom game, for the students to get to know each other a little better. The zoom game is a straightforward game in which students must choose a photo that fits them, either an object or an activity reflecting a hobby, for example. They must zoom in on that photo to obtain 6 different snapshots. They show their team members the photos, starting with the one which has the highest zoom. The team then asks questions that can only be answered with yes or no. If the other students cannot guess what it is, the next snapshot with a lower zoom is shown, and so on.

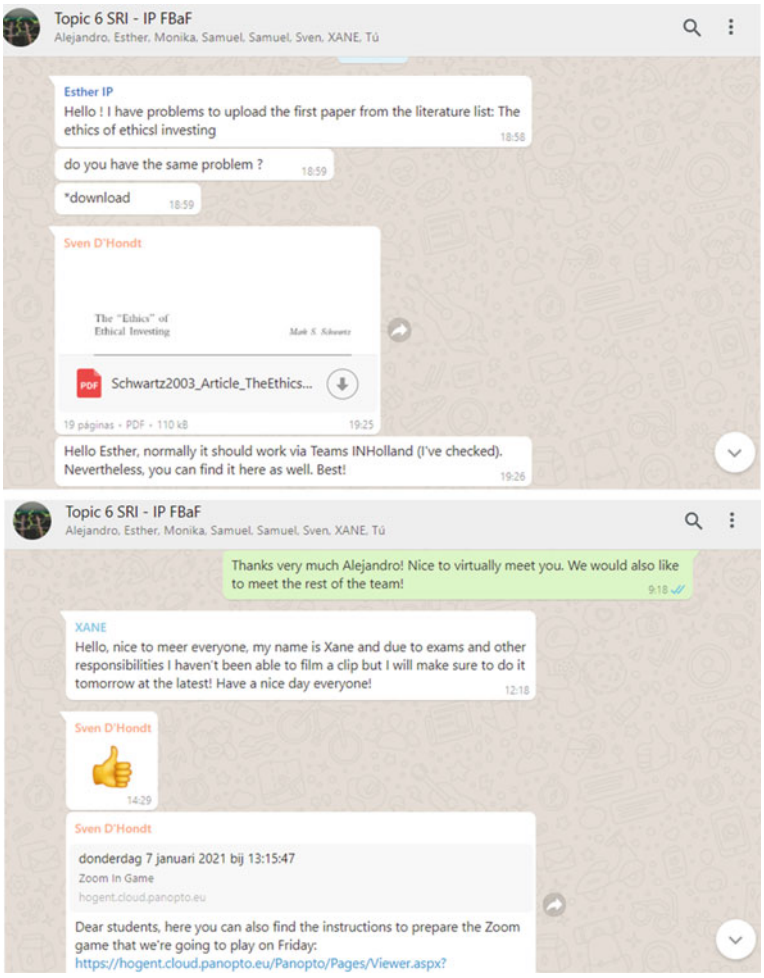

Fig. 6.1 Examples of topic 3 WhatsApp group chats

During this first week, the students must read the literature and prepare an introduction together. Teachers create a shared document in MS Teams called "Introduction". There, the students should explain the purpose of their international paper and some background to their topic, though not the literature review which would be the next step. Students should set out the reasons why the topic may be relevant, socially relevant and possible applications; mention the methodology they will apply or use to compare the participating countries; briefly describe the different sections and content of the paper. Students must take into account that it will be relevant to highlight which is the aim of the international comparison, and what is being compared. They shouldn't forget that the abstract and the introduction of the international paper

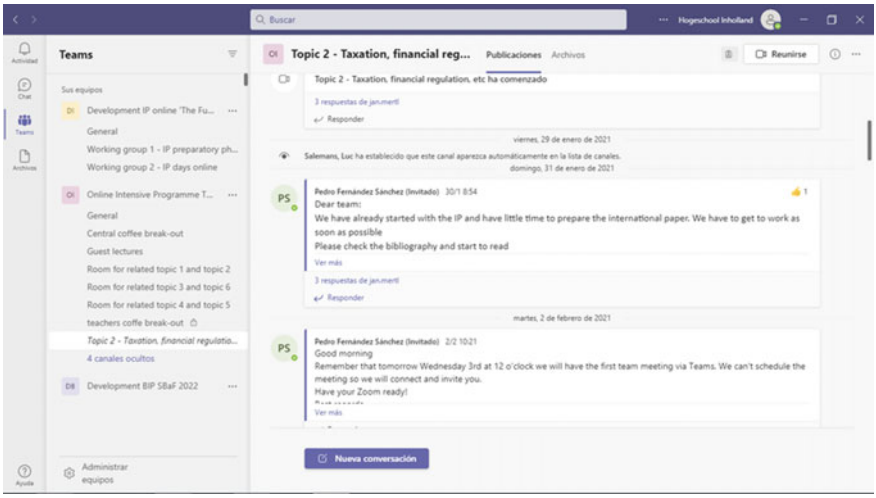

Fig. 6.2 MS Teams environment used for Pre-IP work

are crucial sections which attempt to impress and appeal to the review committee. Although this is a draft, which they can modify, it will help them to organize their work.

(b) Second Week: Students should individually answer the first set of questions. A shared document is created in the MS Teams folder for this called "Questions 1 and 2". This helps the student to reflect on the structure of the paper. Furthermore, another document is shared where students introduce the different sections of the paper. This is called "Paper Topic 2".
(c) Third Week: Students must answer the second set of questions, which is again individual work. Members of the topic should redact the different parts of the topic paper. Teachers provide feedback.
(d) Fourth Week: Students must answer the last set of questions, finalize their topic paper and draw conclusions.
(e) Fifth Week: Students must prepare their topic presentation, while the lecturers provide final feedback on the overall work.

Figure 6.3 shows how the students shared their documents and worked together during the preparatory phase. The shared Word documents allowed for simultaneous work, the use of change control to suggest modifications and the introduction of comments by the teachers to improve the final group document.

Finally, the students had to prepare a video presentation of their topic. Following the Pecha Kucha model (20 slides of 20 s each), they had to present the main conclusions of their research to the rest of their classmates. These videos had to be shared in MS Teams in the "General" room.

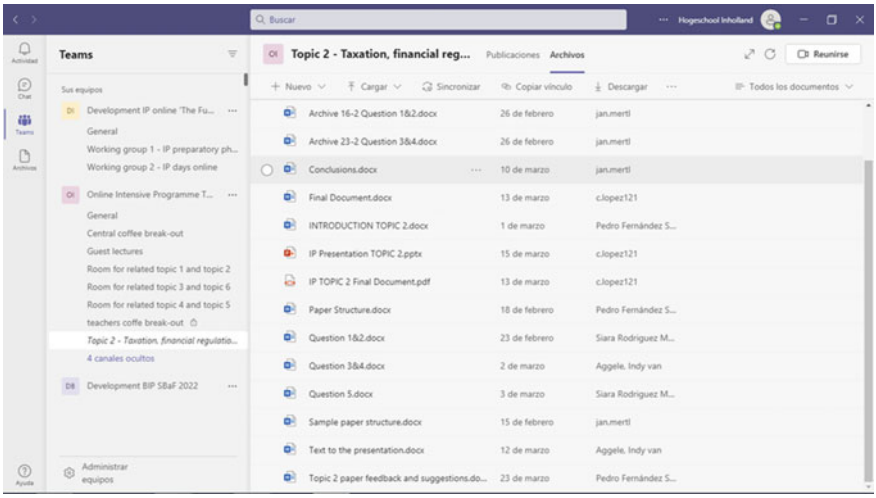

Fig. 6.3 Documents shared by students and teachers of topic group 2

6.5.2 The Virtual Meeting

The first virtual meeting of the IP was celebrated between March 15th and 17th, 2021, via the MS Teams platform. Several activities took place over the three days of the meeting. Several rooms were set up for this purpose. All joint activities were organized in the "General" room. In addition, three rooms were created, one for each of the merged topics groups, so that the students could work during the days of the meeting. There was also a "Conference" room and a "Coffee break" room for teachers only.

(a) "General" room

The opening and closing ceremonies took place in the "General" room. In addition, an intercultural competition between students was scheduled. A virtual escape room activity had been developed using an interactive tool called genial.ly (Fig. 6.4). It included a twofold objective. On the one hand, the virtual escape room was devised as an icebreaker. So far only the students of each topic, who had been collaborating in the previous phase, knew each other.

The escape room allowed students to get to know students from other groups. On the other hand, students could learn more about the cultures of the countries of each of the participating institutions. Conceived as a virtual journey through Europe, five competing teams had to compete to reach the destination, The Netherlands, first. By solving puzzles, quizzes, riddles and crosswords on cultural, economic and historical issues, they moved from country to country.

There were MS Teams breakout rooms set up, one for each of the competing groups. In each group, one student became the "spokesperson". This person shared the screen of his/her computer with the rest of the teammates from the different

Fig. 6.4 Introduction and beginning screens of the escape room

countries and they solved the challenges together as a team. Each time a puzzle or question was solved, detailed explanations were provided. These explanations played an important role. To be able to complete the mission successfully at the end of the escape game a specific question was asked, the answer to which was contained earlier in one of the previous explanations. If students had not been paying attention, they could not finish the mission successfully. On the last screen, students were given a key to email to one of the teachers (Fig. 6.5). The first team to send it would receive gifts.

Teachers could go and visit the different breakout rooms where the students were playing to observe or to provide support if a team got "stuck" in any of the questions. The Escape Room, as we will explain later, was a great success and contributed greatly to the students getting to know each other even though they were hundreds of kilometers apart.

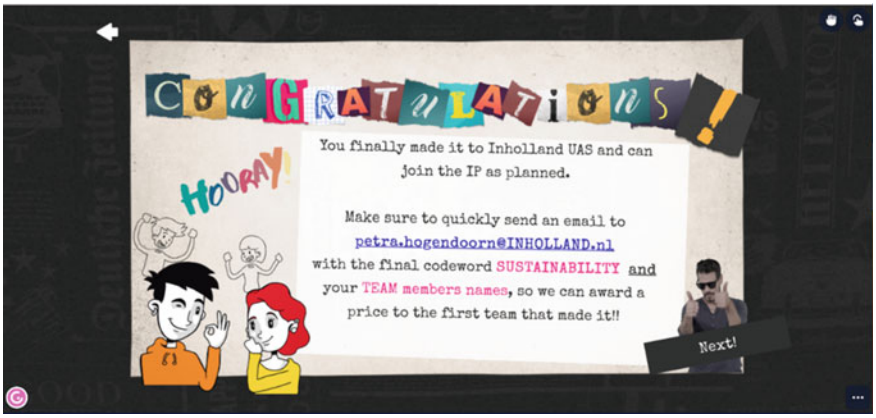

Fig. 6.5 Final escape room screen

(b) Rooms for the joint groups

Three rooms were created for the joint groups to work on the addendum as explained in the previous section. MS Teams was used in the same way as in the previous phase. The teachers could guide and supervise the students' work. At the end of the three days, students had to have finalized an addendum, summarizing how the two topics were interrelated and the main conclusions they had reached.

Taking advantage of the versatility provided by MS Teams, the decision was taken that each of the three joint groups should design a presentation and a question and answer (Q&A) section following a three-step model:

Step 1: In a plenary session of 15 min, each joint group had to make a 10-min presentation followed by a 5-min Q&A. Combining the three groups, the total time of the first phase was 45 min. The number of topic students presenting was 3, and the remaining students and topic teachers were the audience.

Step 2: Three subgroups were created, and the estimated duration was 15 min. Each subgroup had a separate subtopic that was linked to the main topic of the respective addendum. Two students per subgroup took the lead. Students and lecturers subscribed to one subtopic of their choice. They entered the breakout rooms that were created for this purpose. Each subgroup prepared around 3 questions, quotes or graphs to get the discussion among all participants started. Interactive tools such as mentimeter, padlet and slido were used at this stage.

Step 3: With a total duration of 15 min, each subtopic had 5 min to present their concluding remarks in a final plenary session. In this phase, one student per topic group gave a quick summary of the discussion.

Thanks to the flexibility provided by MS Teams, it was possible to create breakout rooms, share screens and use interactive applications, all in a very dynamic way. With a single click, students and teachers could leave the room and go to the one they were most interested in.

Table 6.1 Guest lectures during the IP

Date	Remarks and groups
Monday, March 15th	Integrated reporting related to group 2
Tuesday, March 16th	Experiences from the first Czech financial arbitrator relate to group 1
Tuesday, March 16th	Banks and FinTech—competition or cooperation in supporting SME development—the evidence from ING Innovation Lab, related to group 3

(c) Guest Lecturers' Lounge

In addition, students throughout the IP had access to lectures given by professionals or academics related to the different topics covered within the IP. When the meetings were face-to-face, a master class was scheduled, usually after a visit to a financial institution of reference. For example, when the IP was held in Prague in 2018, it included a visit to the Central Bank of the Czech Republic, where the origins and functions of the Czech Central Bank were explained.

The organizing committee of the virtual IP decided to multiply the number of master classes by three for the virtual IP event. There was one master class for each merged group. Table 6.1 specifies the date and topic of each of the three lectures that were given.

(d) "Teacher's coffee breakout" room

The "Teacher's coffee breakout" room was conceived as a room for teachers only. Here, the academics could exchange views on the IP. This is where the lecturers would discuss different aspects such as how the merged topic groups were progressing, the outcome of the presentations and the final grading of the presented papers by each of the groups.

From what has been explained so far, without the MS Teams platform, neither the preparatory phase nor the virtual meeting itself would have been possible. The next question would be What do the participants think about the fact that the meeting took place virtually? What did they value the most and what did they value the least? The following section will try to answer these questions.

6.6 Results of the Online IP

The organizers of the IP were particularly interested in the success of this new meeting format, in the sense that the objectives pursued would be achieved. To this end, at the end of the program, a survey was distributed via Google Forms to the students asking them about different aspects of the meeting. Out of a total of 32 students from 7 European universities, 23 responded to a questionnaire on different aspects of the virtual IP, resulting in 72% of the students participating in this survey (Fig. 6.6).

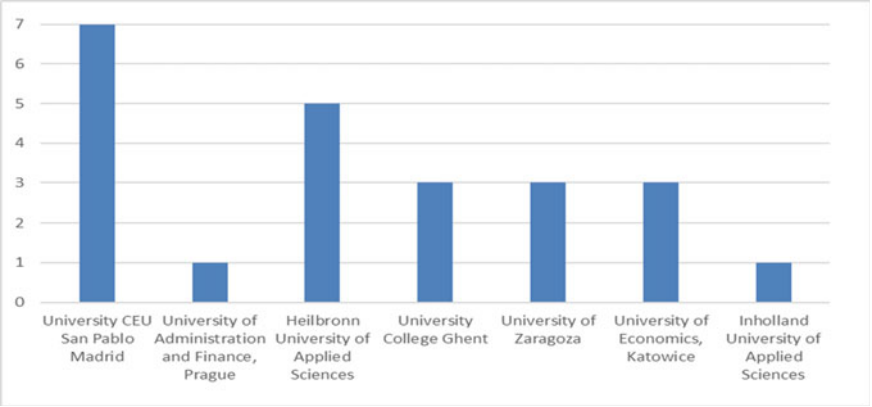

Fig. 6.6 Survey participants by institution of origin. *Source* Own elaboration

As can be seen in Fig. 6.6, students from Madrid were the most active in sharing their impressions of the first virtual IP with the organization, followed by German students. In any case, this is a more than significant sample.

As can be seen in Table 6.2, the participants were more than satisfied with the new organization of the IP. All the sections show a rating above 4, indicating a high degree of satisfaction, in line with what transpired when the IP was carried out face-to-face. Both, the duration of both phases and the dates were very suitable for students. All this resulted in a final IP satisfaction score of 4.30 out of 5. Of all the questions asked, this is precisely the one with the lowest standard deviation and the lowest variation coefficient, which shows that there is a large consensus among respondents on this aspect. It is also interesting to note that the participants consider that this program and its international character will increase their employability opportunities (4.09 out of 5).

On the other hand, and as can be seen in Table 6.3, the participants consider that they have improved important aspects of their education after participating in the IP. 96% of the students agree or strongly agree that they have gained academic knowledge related to the topic of the IP, i.e., about the future of banking and finance. The average score in this section is 4.35. Satisfaction with the skills of working in a virtual team (4.43) and understanding cooperation in a multicultural environment (4.35) are worth mentioning. The acquisition of virtual skills is the lowest rated, with a score of 3.83. It is the only issue where 4% of respondents strongly disagree, hence it is also the only one where the minimum value is 2. The reason could be that during the academic year 2020–2021, students and lecturers had substantially improved their technological skills in this field and hence the IP did not further advance this skillset for participants.

Finally, to identify the strengths and weaknesses of the IP, participants were asked about different aspects of the IP. Table 6.4 shows the results, ordered from the highest to the lowest satisfaction rate on average. The clear winner of the IP was the virtual

Table 6.2 Scoring of different aspects of the virtual IP

	Mean	Mode	Standard deviation	Max	Min	Variation coefficient
How satisfied were you with the date of the IP days (March 15th–17th)?	4,39	5	0,72	5	3	0,164
How satisfied were you with the duration of the IP days (three days)?	4,35	5	0,78	5	2	0,178
Overall rate of the IP	4,30	4	0,56	5	3	0,130
How satisfied were you with the date of the preparatory phase of the IP (January 25th–March 14th)?	4,26	5	0,86	5	2	0,203
How satisfied were you with the duration of the preparatory phase of the IP (seven weeks)?	4,23	4	0,81	5	2	0,192
This IP and the international experience will help me improve my job opportunities	4,09	4	0,60	5	3	0,146

Note 5: very satisfied; 1: very unsatisfied

Table 6.3 Students' perception of skills acquired during IP

	Mean	Mode	Standard deviation	Max	Min	Variation coefficient
Collaborating in a virtual international team	4,43	4	0,59	5	3	0,13
Academically, related to the content of the IP	4,35	4	0,65	5	3	0,15
Understanding multicultural cooperation	4,35	4	0,65	5	3	0,15
Command of English	4,22	4	0,67	5	3	0,16
Building a valuable international network	4,13	4	0,69	5	3	0,17
Online skills	3,83	4	0,72	5	2	0,19

Note 5: very satisfied; 1: very unsatisfied

Table 6.4 Degree of satisfaction with different aspects of the IP

	Mean	Mode	Standard deviation	Max	Min	Variation coefficient
The escape room	4,74	5	0,45	5	4	0,095
The capabilities and expertise of the professors	4,52	5	0,73	5	2	0,162
The overall quality of teaching and coaching	4,52	5	0,67	5	3	0,147
WhatsApp group	4,26	4	0,86	5	2	0,203
MS Teams environment	4,22	5	0,80	5	3	0,189
The quality of the guest lectures	3,96	4	0,71	5	3	0,178

Note 5: very satisfied; 1: very unsatisfied

escape room activity. This would not have been possible without the web-based tool genial.ly and the MS Teams platform, which, as explained above, allowed competition between the different teams that were created for this purpose. In this respect, it scored 4.74 out of 5 with a very low variation coefficient (which indicates agreement on this aspect).

The expertise and experience of the teachers and the quality of teaching and coaching with an average rating of 4.52 were the next most valued aspects by the students. All students recognized the work of the teachers tutoring them in the pre-IP phase and during the days of the virtual IP meeting. Two aspects where the variation coefficient is very high are the WhatsApp group and the MS Teams environment, although in both cases the participants' rating is quite high. The reason could be rooted in two circumstances. On the one hand, there were six WhatsApp topic groups. The way they work varied greatly from one to another. Some WhatsApp groups were more dynamic and efficient than others. In the case of the MS Teams environment, unfortunately there was a worldwide collapse during the IP meeting, more specifically during some presentations, which could explain why some students gave a low score, given the poor experience they had. In any case, the overall high rating of the IP allows us to conclude that MS Teams has overall worked very well and has allowed us to celebrate this virtual meeting.

If we take the data in Table 6.3 as a reference, we can identify aspects where there is still room for improvement for future meetings. Mainly the guest lectures offered to students have the potential to be enhanced. In this regard, it is necessary to point out that it is rather challenging to succeed in all lectures being interesting for everybody. On a positive note, the virtual format introduces the flexibility to incorporate various master lectures from different parts of the world, over the course of several days. This was not possible when the event was celebrated on-site.

6.7 Summary and Looking to the Future

The pandemic has forced us to adapt to a quarantined world. It has affected all areas of our lives, from the personal to the professional. While human losses can never be compensated for, it is necessary to point out that because of the pandemic and in the field of education, many positive changes have taken place. Education has been one of the sectors that has adapted most quickly to the new situation, with the help of large IT companies. In a matter of hours, education professionals had to move from giving classes in person to teaching online.

In this chapter, we have described the experience of transforming an intensive program, which aimed to enhance students' autonomous and collaborative work in a multicultural environment through project-based learning, into a virtual one. Based on the experience accumulated during the toughest months of the pandemic and Microsoft's development of a tool, MS Teams, which allows for remote collaboration, teachers from seven European Institutions worked ceaselessly to adapt the existing program to face reality: a Europe with closed borders. The different paragraphs have pointed out how the new event was organized, and the role MS Teams played in it.

Based on student feedback and survey results, the meeting was a success, although participants still prefer face-to-face meetings. Looking ahead to a post-pandemic world, the IP organization will be maintained, with a pre-IP phase, in which MS Teams will continue to play a leading role, and a face-to-face on-site encounter. However, the MS Teams platform will continue to be used also during the face-to-face event, as it allows students to share documents and work together on the scientific paper easily and efficiently.

And finally, the plans for the future of this IP and the consortium of participating Institutions include a return to an on-site culmination event. The vision is to combine the online preparation with short-term physical mobility abroad, to one of the participating institutions during the IP-week. Prior to the physical mobility, a mandatory online component facilitating collaborative online learning and teamwork would remain the preparatory phase, very much as has been done during this past edition of the virtual IP. This hybrid program, or a so-called "Blended intensive program", would be receiving funds from the European Union in the framework of ERASMUS+. This type of funding is provided to blended IPs that cater to new, innovative and creative ways of teaching and learning via virtual cooperation.

Acknowledgements The new design and implementation of the virtual IP in 2020–2021 was made possible thanks to the joint effort of the following professors whom we would like to thank for their dedication and commitment: Petra Hogendoorn-Schweighofer, Luc Salemans and Twan Franken (Inholland University of Applied Sciences), Jana Kotěšovcová an Jan Mertl (University of Finance and Administration in Prague), Ana Yetano (Universidad de Zaragoza), Sven d'Hondt (University College Ghent), Joachim Vogt (Heilbronn University of Applied Sciences), and Monika Foltyn-Zarychta and Joanna Błach (University of Economics in Katowice).

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Chapter 7
Historical Architectural Heritage as a Generator of Real Immersive Educational Environments for Project-Based Learning

David Villanueva Valentín-Gamazo, Nelson Tuesta Durango, M. Isabel Mansilla Blanco, and M. Cruz Rey de las Moras

Abstract The tangible cultural heritage encompasses a whole range of architectural property in the form of monuments, ensembles, and sites. This heritage shows features from our territorial construction of the past and also values of historical, social, cultural, even economic character of the community. The layers that have given rise over time to heritage architecture structure a kind of palimpsest, open to knowledge. The skill objective of the Rehabilitation, Restoration, and Pathology course in the Degree in Technical Architecture offered at the European University Miguel de Cervantes focused on developing practical work on historic building. Architectural heritage is, therefore, placed at the center of the teaching scenario, and Project-Based Learning active methodology becomes a valid mechanism of articulation of the teaching–learning process. Taking a real old building complex, for the students to study and share a project, provides an educational immersion context in its physical reality, placing the students in the situation of their future professional practice. It is noteworthy that the memorable experience generated provides skills and learning outcomes as well as awareness of cultural heritage's value in general, and architectural heritage in particular; cornerstone on which to build the principle of universal preservation of this legacy.

Keywords Technical architecture · Built heritage · Project-based learning (PBL) · Community learning · Real immersion

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_7

7.1 Introduction

Historical heritage has been representing a particular field of study in the Engineering and Architecture branch. It has been approached from various courses, compulsory or optional, oriented to the acquisition of competences to preferably intervene in building complexes and ancient constructions; whose nature supposes, in general terms, to recognize, interpret, diagnose and project on the basis of vestiges that have been transformed, preserved, affected, recovered, etc., as time passes by. These are generated by the combination of layers derived from the action of nature and human construction, culminating in a kind of active palimpsest, open to the intelligent action intended at any given moment (ICOMOS, 1995).

Thus, it is necessary to know the architecture of the past, to understand the evolution of the building, and to decipher its meaning in each era; because, in most cases, the work does not arise from a single project, since it is the result of a social construction materialized over time (Ll, 2000). Recognizing and learning how to conserve, recover, and improve the altered parts is vital in technical architect's training, called to intervene in the building process as an architectural technician. These professionals' training brings together knowledge in architecture theory and history, aesthetics and composition, construction materials, structures, construction systems, equipment, machinery, and auxiliary means of work, among other areas. A whole compendium of knowledge through which to build the student's critical, creative, and divergent thinking, and that of the future building expert as well.

Preparing students to acquire the course's learning outcomes not only helps them to be able to develop their working careers, but also contributes to awaken an interest in historical constructions. Understanding the value of architectural heritage, from the educational stages, reinforces a vital attitude of respect for the vestiges inherited from the past; a stance aligned with the objectives promoted by many institutions, including the United Nations Educational, Scientific and Cultural Organization (UNESCO, 1972).

In order to achieve the intellectual, human, professional, and social training objectives of the corresponding course (Zarzar, 1994), the methodology should be used by the teacher to structure, order, and plan his/her teaching activity. When we find ourselves, as in the present case, in an educational context related to the Degree in Technical Architecture, this marks the need to teach how to develop a constructive intervention project on an old building. The so-called active methodologies constitute an interesting system that will allow the students' collaboration and cooperation in a coordinated group practice combining different perspectives with an operational mode similar to that used in their future professional practice, generating a learning community as well as enriching socialization (Alba, 2016).

There are three methodologies, among other models (Design Thinking, Gamification, Inverted Classroom, Cooperative Learning), structured according to a team participation dynamic, focused on helping students to respond to a specific situation related to their reality and professional field. Unlike Challenge-Based Learning and Problem-Based Learning, Project-Based Learning (PBL) (Heard, 1929) is a type of

active teaching ideal for students to build knowledge and apply it in the resolution of a project, working within the framework of a multidisciplinary approach in small groups and under teacher coordination (Pecore, 2015). The practice unfolds in a formative scenario where students experiment with the building/construction and actively use the knowledge acquired, motivating them to seek new solutions or to inquire more about what they have learned. And all this, having the opportunity to share it with team members and with other classroom mates, favoring significant individual and collective learning (Ausubel et al., 1983), in addition to enlivening joint social responsibility for heritage.

7.1.1 Academic Perspective: Learning the Technique of Architecture

The Degree in Technical Architecture gives access to a regulated profession. Curricula leading to this discipline degrees are therefore governed by Order ECI/3855/2007, 27 December, which determines the acquisition of minimum skills classified into modules, one of which, dedicated to Building Techniques and Technology, encompasses the area of intervention in existing historic buildings. Thus, students must have knowledge on traditional materials and construction systems and the historical evolution of techniques and construction elements and structural systems having given rise to stylistic forms. In addition, they will develop the ability to rule on the causes and manifestations of injuries and propose solutions to building pathology together with the ability to intervene in rehabilitation, restoration, and conservation of the built heritage.

7.1.2 Professional Perspective: Using Professional Architecture Technique

The technical architect maintains a direct connection with the building and the construction sequence, making construction execution management one of his/her main vocations and professional attributions. The work environment par excellence involves operating in the construction phase, collaborating in different intervention types: new construction, rehabilitation, restoration, conservation, maintenance, prevention, health, and safety, etc. The typology of actions on historical architectural heritage constitutes a specific area of specialization within the Technical Architecture field. It has a strong significance in the skills and abilities of the discipline because both the knowledge and formal, material and constructive interpretation, find its meaning in working to solve problems such as pathological and damaging processes suffered by these construction types. And all this happens in situ, where the building is located, when studying and analyzing the construction in its project phase, and

when directing its execution, in the construction stage, when the technical architect participates as an expert agent in the field with greater responsibility in the control of the correct use of the projected architecture's technique.

7.1.3 Immersion in a Real Training Environment: Learning Through an Existing Building

If we wish to translate the mechanics of defining a project in the professional world, aimed at specifying the action on a heritage building to an academic environment, we need to assess how to establish the architecture type to be studied/intervened as a starting point. Therefore, we have to decide whether to take an existing building as a basis, design a hypothetical case, or apply a hybrid context (Table 7.1).

We are talking about moving between the real or unreal limits when conceiving the exercise. One side requires a building location suitable for educational purposes, both in its appropriate and safe architectural reason and in the possibilities of access to it, since these conditions are not always present and, if this way is chosen, the logical thing to do is to visit it. In this sense, it is essential to consider the state of conservation and evaluate possible risk situations for students, even if provided with protective and safety equipment. The teacher will make a prior visit and will request permission from the property if necessary (Fig. 7.1).

The other side concerns the generation of a totally imagined theoretical scenario, both the building and its location, or framing it in a precise place. As an intermediate solution, the heritage object could be based to a greater or lesser extent on a real building, from which parts are taken and others are modified and enlarged, according to the purposes pursued, locating it in an place conformed with the criteria of the previous casuistry (Fig. 7.2).

The immersion degree offered to the student can be an interesting factor when choosing one of these paths, if it is also intended to facilitate the professional environment connection, under conditions that, although simulated, are as close as possible to reality. In this sense, using an existing building, in its current state, provides the appropriate materials for the student to have the opportunity to recognize, identify, diagnose and draft actions, learning in situ from the direct understanding of the language dictated by architecture and ancient technique.

Table 7.1 Learning scenarios with buildings

Real building	Case/Context/Current situation	Physical Accessibility	Direct building contact	Complete immersion
Theory building	Case/Context/Hypothetical situation	Non-physical accessibility	No contact with building	Incomplete immersion
Hybrid building	Case/Context/Hypothetical situation	Partial physical accessibility	Possible contact with building for reference	Incomplete immersion

Fig. 7.1 Example of a real training environment in an existing building

Fig. 7.2 Examples of a training environment based on a theoretical building (left) and training environment based on a real building (right)

Taking into account that Project-Based Learning active methodology can be applied to any subject, this paper describes the proposal of interventions in existing historic buildings as well as its implementation advantages since the 2017–18 academic year in the Rehabilitation, Restoration and Pathology course, taught in the Degree of Technical Architecture at the European University Miguel de Cervantes (UEMC) from Valladolid. Thus seeking to take a step beyond the usual approaches of work and projects on theoretical case studies in order to generate a real building learning space.

7.2 From the Construction Project to the Academic Project: PBL in Historic Buildings

Having chosen the way of taking a real case as the project context, based on a constructed building, the next step involves the specification of PBL methodology applied in the execution of the course work. We are starting from the premise of transferring the dynamics of the work project to the academic project in order to

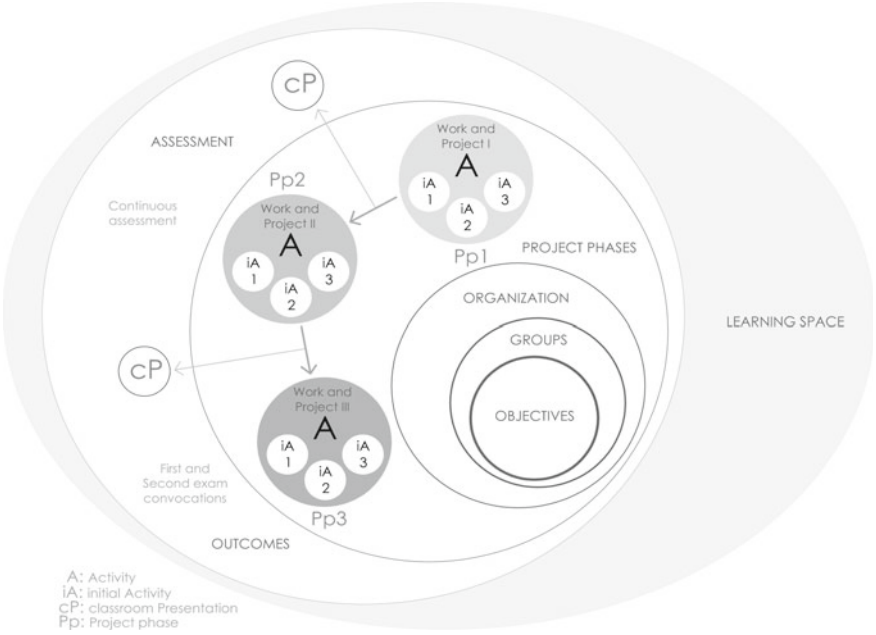

Fig. 7.3 PBL organizational model generated

integrate the professional intervention process. We will also try to ensure that students of the Degree in Technical Architecture acquire the skills, knowledge and skills—individually and cooperatively—in a similar community and socialized environment to that of their future career. The model designed for the course project development is inspired by some of the systems generally used in the profession for similar actions (González, 1999; Onecha et al., 2018). Although the basic structure tends to be similar, it is reasonable for each technician to use a particular procedure, appropriate to his/her preferences, experience and professional vision and, obviously, adapted to the characteristics of the building to be intervened.

The course teaching method is organized in a cycle of connected stages (Fig. 7.3):

1. Learning Space.
2. Objectives.
3. Groups and Organization.
4. Project Phases.
5. Assessment and Outcomes.

7.2.1 Learning Space

The learning space configuration on an existing historic building implies a previous research work looking for buildings suitable for the proposed objectives and for

students to develop the competence framework attributed to this type of activity in the subject file of the course, integrated in the curriculum. The building may be part of a historical site or an independent real estate property, and may have a greater or lesser degree of protection. It could be unlisted, but it is important to assess in its choice, whether it is close to the university campus, access is adequate and the property grants permission to enter in order to facilitate student's technical visits. Once the external and complementary training environment has been selected, it is time to finalize the subject matter, the project phases tasks and the definition of a title identifying the object of intervention. All of it is to be able to ask the students the question: Shall we rehabilitate, restore, or conserve it?

7.2.2 Objectives

As in any project process, it is important that the students know from the beginning the general and specific objectives to be achieved, both as a group and individually, in the latter case, mainly related to learning outcomes. The premises to be achieved are established in the general statement, offering a global vision of the activities purpose, relating them to methodology and parts of the work, so that students are aware of this association from the beginning.

7.2.3 Groups and Organization

Teams should be formed early, once they know PBL scope to be developed. In the first class, preferably, or in the initial week, students are divided into small groups, according to the number of students enrolled. Groups are explained that they will work on a common building and that each team will be assigned at least one specific architectural unit to constructively design the intervention. Group formation determines the student's participation in a collective work dynamic. To facilitate task organization, each team members appoint a project coordinator, who plays a leadership role and acts as spokesperson with the teacher. This managerial functions' attribution allows the teacher to better check each phase' progress, attend groups' needs, and give the students supervisory responsibilities. These could be typical of the discipline, for example, when they prepare and carry out the technical visits to the building or when they write the project in a work assimilated to that of a technical office. Although the line of action is group-based, students are always invited to share their progress autonomously and through joint classroom presentations, favoring cooperative learning. As for the means of communication and information sharing, they can use any system, taking advantage of ICTs, being Dropbox, OwnCloud, WinRAR, and WhatsApp the most common.

7.2.4 Project Phases

It constitutes the nucleus of the practical work proposed according to the usual scheme of a professional project, and forms the master pillar of the teaching–learning system, developed in three phases:

- (Pp1) Work and Project I. Previous recognition.
- (Pp2) Work and Project II. Integral knowledge.
- (Pp3) Work and Project III. Intervention techniques.

Each work, project or project-phase has specific objectives, activities (A), oral classroom presentations (cP), and evaluation criteria, in line with the course's Teaching Guide. Part of the tasks is proposed as initial activities (iA) in order to stimulate the groups to start the first steps of each of the three stages of performance tasks (Table 7.2). Classroom oral presentations, creating an environment of collective learning and reflection, are organized in two structural levels associated with initial activities and complete activities. The first type corresponds mainly to monitoring and showing progress in the achievement of each stage's first activities. The second category is the group oral presentation presenting the result of a work and project, with the support of a digital presentation, evaluated by an oral test rubric.

7.2.5 Assessment and Outcomes

PBL work assessment in the course is organized as follows: Continuous—first examination call (end of course)—second examination call (Final). As the students carry out the activities' partial deliveries during the semester, according to the Teaching Guide's deadlines, the professor would grade the work. Tutoring or seminar sessions are used to share the results and as a feedback mechanism to guide the students in the best resolution of the assignments. In first and second exam convocations, students have the possibility of handing in the activities again, maintaining their group identity, in order to obtain a passing grade or a higher one, as the case may be. In one stage or the other, it is a necessary condition to achieve a group grade of 5 or above in each of the three assignments and projects, as well as in the assessed oral defense tests.

7.3 Lessons from the Project Process: Previous Recognition, Integral Knowledge, and Intervention Techniques

The three phase activities of coursework execution (Pp1. Previous recognition, Pp2. Integral knowledge and Pp3. Intervention techniques) make it possible to compose the lessons of the project process. Their organization, although given in an order, because

Table 7.2 Project phase activities

		Work and Project I Previous Recognition		Work and Project II Integral Knowledge		Work and Project III Intervention Techniques
Activities (A)		Documentary research	Classroom Presentations (cP)	Constructive units of action	Classroom Presentations (cP)	Priority actions
		Previous analysis		Architectural survey developed		Preliminary actions
		Prediagnosis		Diagnosis		Interventions
		Initial architectural survey		Pathology and diagnosis		Constructive development
		Degree of preservation		Preliminary study and project		Technical appraisal
Initial Activities (iA)	Initial Classroom Presentations (icP)	Preliminary location and information search	Initial Classroom Presentations (icP)	Complementary technical visits	Initial Classroom Presentations (icP)	Priority, preliminary and intervention actions
		Prediagnosis sheet design		File consultation		Choice of best available techniques
		Organization of first visit to the building		Architectural survey to scale		Construction sheets and planimetries of the technical solutions

one stage results give way to the next, does not follow a strictly temporal criterion but connections are produced in a network system from these chained phases. Project activity involves back and forth journeys to confirm and reaffirm the steps; it should consequently be understood as a work where everything is interconnected, and the ultimate goal depends on the success of each part of the whole.

7.3.1 Work and Project I. Previous Recognition

7.3.1.1 Documentary Research and Previous Analysis

We could say that an architectural project development involves a creative journey focused on two paths coexisting in the same direction. One of the research involves the influences of reference sources (Campo, 2017). Another inspiration path is greatly linked to the person's cultural background. The research field weight becomes especially latent when the project addresses the intervention on an existing building, and we do not start from scratch. Knowing and recognizing the heritage asset in the most complete and adequate way is an essential premise. The information we have will facilitate decision-making and its justification when rehabilitating, but especially when restoring and conserving. These latter actions, in which what and to what extent to suppress or, in correspondence, to maintain, are key for decision-making. Research covers historical, sociocultural, and economic fields associated with the actions, together with the architectural plan, of the vestiges under study. Students consult sources related to archives, registries, libraries, regulations, geographic information systems, etc. They learn the value of a closer knowledge of the heritage in order to understand the reason for the place and the architecture it contains.

As part of the research work, the documentary and information findings are followed by the preliminary analysis of all these materials to establish a first approximate context, but based on a reference that, a priori, paves the way for a building knowledge before contacting its physical reality. The analysis at this level makes the student cover various aspects: location (access, urban situation, property and/or plot, topography, orientation, etc.), form and function (basic geometry, general program, global uses, etc.), and the historical-constructive evolution (description of the historical data and construction process of the built complex).

7.3.1.2 Prediagnosis

For the primary global approach to the building, an initial documentary research study and the elaboration of a data collection sheet for the visit to carry out a pre-diagnosis report would be helpful. Before setting out on the trip, each group of students is assigned a construction unit to work on, when the building is large or the subject matter requires it.

The team coordinator distributes functions and they prepare together the instruments to be taken, the access mode and the site reconnaissance route, in the classroom. During the first technical visit, accompanied by the teacher, the groups use the pre-diagnosis data collection sheet to corroborate and compile written, graphic and photographic information regarding, for example, building (general description, urban situation, site and location, supply services, etc.), materials and construction systems (foundations, structure, envelope, partitions, finishes, installations, etc.), heritage elements of interest and state of conservation.

7.3.1.3 Initial Architectural Survey and Degree of Preservation

As a result of this previous inspection, each students team also has the opportunity to elaborate the architectural survey with the objective of representing a built reality graphically to scale (González, 2009). On this occasion, the geometric information and the material and constructive reality of the building is translated into drawings and annotations at the sketch level, drawn in situ; thus laying the basis for the measurements and architectural aspects of the current representation (Latorre & Cámara, 2010). The measurement technique is usually trilateration, applied by using a tape measure and laser distance meter, with which plans, elevations, and sections are sketched. In addition to the sketched planimetric result, including location and site plans, the students explain the methodology and processes applied to execute the first direct survey. Drawings translated to another scale and definition level at a later stage.

As a conclusion of Work and Project I, and a prelude to the following project process, the initial knowledge and recognition allow us to define the real architectural conditions of the heritage property, as well as to characterize its degree of conservation; justified with a categorized written description (ruin, semi-ruinous, regular, normal) and with photographic resources of specific parts of the building. This starting point will mark, to a great extent, the scope and type of constructive action.

7.3.2 Work and Project II. Integral Knowledge

7.3.2.1 Constructive Units of Action and Developed Architectural Survey

Once the building has been globally analyzed, each group develops the particular study of the construction unit assigned. The segregation is proposed by the teacher, for which, if possible, the building will be divided into the same parts as the number of groups covering the entire construction. If the team number is bigger than the number of work teams, the value and architectural interest will prevail when deciding the assigned area. In the division into parts, it is convenient to form each studied module

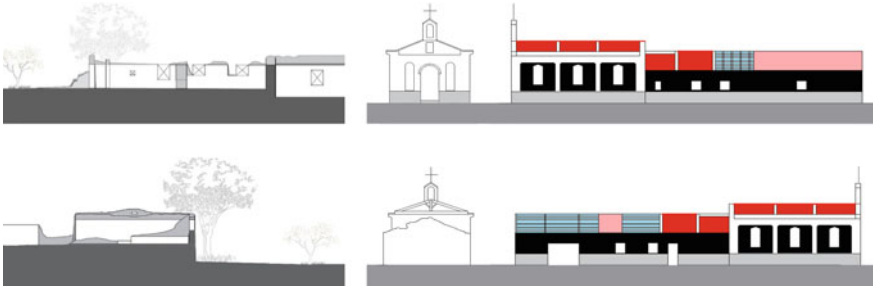

Fig. 7.4 Students' works: planimetries of the current state of the building

by integrating contemporary, constructively or spatially related areas, functioning as autonomous units. When combining all of them, the whole is obtained by addition, rather than by superposition.

Work is carried out on the so-called delayed survey, on the basis of the direct survey, carried out in situ during technical visits. Research work continues in order to achieve the already comprehensive knowledge of the built object, understanding and documenting its physical materiality and execution rhythms, and all the functional, historical and heritage significant values concerned. Representation becomes detailed, at a precise metric and dimensional scale where the choice of graphic expression language is essential when showing the architecture (Almagro, 2004). Students generally use computer-assisted drawing tools in this activity performance. Digital techniques allow them to easily combine the information individually worked within the group. In this sense, it is recommended to generate a construction unit reference mesh with the main vertices referenced in coordinates so that they can verify if the result matches with the pre-established base at any time, seeking to obtain the most accurate and complete representation possible. From a documentary point of view, the architectural survey developed includes general situation and site planimetries, according to urban planning regulations, property/plot urbanization, floor plans, graphic report of construction systems and pathological processes and constructive lesions (Fig. 7.4).

7.3.2.2 Diagnosis and Pathology

Students continue to advance in the knowledge of the building and its context through the development of specific preliminary studies. The objectives and first hypotheses are set for testing from previous analysis data and on the survey basis. This process phase consists of a systematic collection of information in all areas where further research is needed, particularly in the following:

- Historical study of the built complex and of the construction units, with a description based on historical and construction data to explain the evolution of the building process.

- Architectural study of the built complex and of the constructive units, with a description justifying the architectures' functional reason and their connection with the surrounding place and territory.
- Constructive study of the units, in the form of a report on the materials and construction systems.

These works will serve to carry out a diagnosis or previous reflection aimed at the specific recognition of the building's real state of conservation with respect to the essential requirements, the understanding of its historical, architectural, constructive reality, etc., without forgetting the identification of factors or problems affecting it. One of the fundamental complementary technical studies for diagnosis reflection or synthesis is the identification, characterization, and valuation of the damage present in the construction. Pathology has a significant influence on a building conservation state, hence the importance of knowing the process or causes having originated them. Students must explain the physical, mechanical, chemical, and biological issues detected on technical sheets whose format is provided. Among other information, they describe detection type and form, the damaged element, affected construction materials, location, date of appearance, symptomatology, etiology, diagnosis, prognosis, recommendations/observations, photographs, location plan, and construction details (Fig. 7.5). They also prepare other files on construction materials and products, construction systems, and equipment.

The building unit diagnosis involves students evaluating and reflecting on the conservation state in order to determine the intervention needs and form. The evaluation phase aims to achieve a global vision of the unit by recognizing its architectural values and signs, based on the observations and analyses carried out in the multidisciplinary diagnostic studies. The critical reflection stage will help them to confirm the hypotheses raised in previous investigations, the new ones that have arisen, obtaining a final synthesis of the building reality.

Fig. 7.5 Students' works: constructive pathology and preliminary project planimetry

7.3.2.3 Preliminary Study and Preliminary Project

The final activity of project phase II culminates with the preparation of the preliminary study and the preliminary project. Through the preliminary study, the working groups are asked to present in the classroom, in an elementary and schematic way, through sketches or basic drawings, the ideas and the project approach to be developed in the intervention, whether it is rehabilitation, restoration, or conservation. Once the proposals have been confirmed with the teacher, students present the general characteristics of the intervention—functional, formal and constructive—in the preliminary project, presenting the following documentation:

- Report: general and constructive description of the interventions in the unit/s of action and description of the project criteria to be applied in accordance with historical heritage legislation and international restoration-conservation charters.
- Intervention proposals: graphic description in the form of a sketch of the various alternatives proposed for restoring/rehabilitating/conserving the building.
- Plans: project plans at a basic level with the formal definition of the restored/rehabilitated/conserved building (Fig. 7.5).

7.3.3 Work and Project III. Intervention Techniques

7.3.3.1 Priority and Preliminary Actions

The third phase of the project continues to be developed on the construction unit or units assigned to each work group. Once the conservation degree has been assessed and proposals for action have been made in a preliminary project, the students evaluate the parts where priority should be given to intervention. In this case, the decision is mainly based on the analysis results and reflection on the pathological processes suffered by the building and the present constructive lesions. Prioritizing the most serious ones, associated with situations of loss of stability and resistance of the structure, as well as the elements with high patrimonial value in threat of ruin. Once damages have been determined, they are described, justifying the intervention's prioritization, represented graphically in plans and the location and affected areas.

Depending on the property's condition, if it has been in disuse for a long time and lacks the required maintenance, prior actions are usually required in a double sense: conservation and security. The parts in loss danger due to serious deterioration caused by movement in the building will be the priority in taking consolidation and strengthening measures to achieve its stabilization and resistant capacity. Foundation settlement, load-bearing walls collapse, arches and vaults deformations, parts detachment, etc., are the cases considered. Structural safety techniques, such as shoring and underpinning, will be projected both in the report and planimetry by the students as a solution to these previous conditions, using from traditional systems to modern technologies, according to the study context. The risk to people's health and safety

arising from the above scenarios will determine the preventive actions' approach for signaling and protection. Stimulating student teams to assess how to intervene with project methods in terms of prevention and safety on site, another of the technical architect's professional tasks.

7.3.3.2 Interventions

This is one of the teaching and learning methodology's main activities where the students describe the project's interventions. The techniques of architecture, as mechanisms of action in buildings, serve to respond to the needs or requirements when the existing properties and characteristics are not adequate. Relying on the interventions map generated, the students select the best available techniques, among those offered by the manufacturers and the adapted and designed technology. They implemented them on the registered state of the building to, if necessary, rehabilitate, restore and conserve the architectures. The data and characteristics provided by the trademarks serve to justify the actions and complement the particular studies carried out by the work team, always bearing in mind that the academic purpose of the project grants certain licenses in decision-making. However, within the framework of a sustainable, intelligent, and socially responsible approach, the aim is to instill the prevalence of technical, economic, and environmental factors. Intervention techniques are classified according to the construction part or phase where they act:

- Demolition: the process of partial or total removal of the material that makes up the construction systems by manual and mechanical means, considering the order of disassembly and waste management, defining the technique type: pushing, compression, pounding, percussion, shearing, drilling, or cutting. Paying attention to risk prevention and occupational health and safety.
- Foundation: Settlement in the building support requires consolidation methods and treatment by underpinning, reinforcement and replacement. With the first two, in the event of soil support capacity problems, the aim is to stabilize the foundation. With the third, they seek to strengthen the resistance if the support is insufficient and the system is usable and, when it cannot be maintained, they apply the fourth technique by replacing it.
- Structure: thinking about intervening on a historic building load-bearing systems leads them to propose the application of techniques to consolidate and reinforce structures. Stone, wood, and clay are the main materials traditionally used for load-bearing walls, floor slabs, and roof reinforcement. They act by strengthening, reinforcing, and replacing damaged load-bearing elements, proposing solutions, for example, for bracing and installation of components reproducing the damaged ones while meeting structural safety requirements.
- Cladding: with the methods applied to enclosures in contact with the ground, facades, roofs, and openings, the aim is to solve, as usual conditions, situations of humidity, condensation, thermal transmission, cracks, fissures, material loss,

and dirt. The environmental factors' control is the main objective to be achieved through cladding, combining the ornamental, formal, and functional criteria of the building.

- Coating: finishes and finishing materials are a field of study related to the coating and interior partitions because, due to the interdependence of both building systems, they are also affected by causes dependent on external actions. The techniques chosen by the students offer advantages in the presence of water, the existence of thermal-acoustic bridges or condensation formation.
- Installations: as building facilities constitute a specific course in the technical architect's training, the machines, equipment and systems' repair, restoration and installation are addressed in a general way. Students are aware in this way, of the facilities' influence on the existing construction. They can consequently close the design circle of the natural sequence of building execution.

In the choice of intervention techniques in existing buildings, students should logically attend to the material and technical characteristics of the construction systems subject to intervention, guaranteeing the compatibility of the new with the existing, avoiding the appearance of harmful or damaging interactions. These proposals have to comply with the determinations established by the Technical Building Code (TBC)-buildings regulation in Spain-regarding the assurance and verification of the referred compatibility (TBC, 2019). Likewise, in addition to projecting solutions for what has already been built, it is necessary to include construction methods inspired by the ancient or totally modern work, which would materialize the new architectures of restoration, rehabilitation, and consolidation. This includes both interventions keeping it and those modifying it.

7.3.3.3 Constructive Development and Technical Appraisal

The constructive development completes the description of the chosen intervention techniques. The characteristic graphic representation shows the construction's global section, or of the main constituent parts, as well as their particular findings. Priority is given to foundation, ground containment, façade start above ground level, outline of openings, floor slabs, roofs, and skylights, if any. The solutions' constituent layers are referenced by coding and descriptive text, providing the exact information of the materials' constructive definition and their manufacturers. Students are instructed in the necessary coincidence that must exist between all the project documentation (report, specifications, plans, and budget).

Lastly, and continuing with the partial conclusions obtained in the two previous project phases (Pp1 and Pp2), students have to issue a final global technical evaluation of the project method and of the actions proposed in accordance with the planned objectives. Highlighting the strictly constructive value or even including other perspectives: economic, environmental, social, etc. The integrated approach is recommended because it provides a deeper level of reflection and enriches students by comprehensively identifying what the planned interventions contribute to the

building, its environment and society. Architecture technique intervenes in multiple factors: functional, formal, material, ornamental, etc.; therefore, learning to apply it sensibly and in a cooperative way intrinsically teaches human and social values, such as the effective use of space, economy of means, environmental protection or access to heritage and social inclusion.

7.4 Results

The outcomes of PBL methodology framework application to historical buildings are shown in first instance with the project phases deliveries (Pp1, Pp2, and Pp3) carried out by the student groups. The technical document presented in the format and within the deadline established in the course is tangible proof of the process followed, of the collaborative work developed and of the suitability of the solutions given to the problems presented, all of which is assessed in accordance with the evaluation criteria related to the method and published in the Teaching Guide.

In turn, the teaching surveys arranged by the University Polytechnic School, the center where the degree is taught, are a good indicator to analyze the impact of using a real building as a resource for immersion in an educational environment similar to that of the professional context. Students anonymously complete a survey for each enrolled course at the end of the semester. The questionnaire, measured on a Likert scale from 1 to 5 plus the answering option: don't know/no answer, consists of a question list divided into blocks (Teaching Guide, Teacher Performance, Academic Tutorials, Learning Outcomes, and General Satisfaction). Among the items for the Rehabilitation, Restoration, and Pathology course, those most directly related to the teaching and learning methodology assessment (1 to 8) have been selected:

1. Information on the objectives, contents, and methodology contained in the teaching guide.
2. Activities' Organization and Structure.
3. Resources used to promote learning.
4. Participation encouragement and planned activities' interest.
5. Learning encouragement by improving knowledge and skills.
6. Tutoring helps achieving intended learning outcomes.
7. Satisfaction with achieved learning outcomes.
8. Satisfaction with the training received in the course.

The data shown in Fig. 7.6 correspond to the 2017–2018, 2018–2019, and 2019–2020 academic years, with a level of student participation in the survey above 75% in the first two, and below 50% in the last one. The 2020–2021 academic year has not been included due to lack of information.

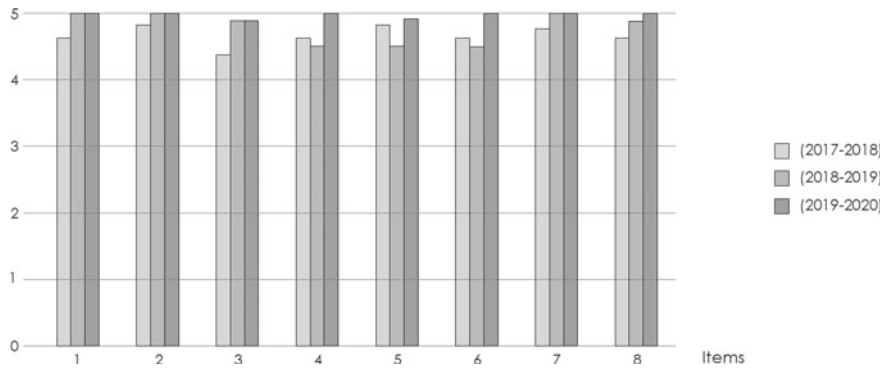

Fig. 7.6 Teaching survey results

The scores for the items are overall positive, mostly above 4.5 points. The appreciation of methodology, activities' structure and organization, participation encouragement, learning acquired and training received, is particularly high. PBL consolidation, its better adaptation to the students' learning progress and the teaching experience obtained throughout the courses allow explaining how in the 2019–20 course the satisfaction level has increased to reach 5 points in mostly all the items. Although students interact with a real building that offers all the materials for the work achievement, the difficulty involved in the direct interpretation of the study object makes that item 3 (4.9 points) does not reach a 5 even providing a large amount of resources. And neither does item 5 (4.9 points) because, given the system's cooperative strategy, students must adopt an active and collaborative position that is difficult for them to assume sometimes.

The influence of the difference in the number of students per team seems reflect slightly lower scores on items 4 (4.5 points), 5 (4.5 points), and 6 (4.5 points) in the 2018–19 survey data. Groups formed with three members instead of two, distributing the workload among more people and affecting the level of participation in the activities. In a certain way, some students perceived less individual attention given from the teacher in tutorials, motivated by this greater diversification in the commitment to task execution and in the weight of coordination by a designated student, with other classmates benefiting from the situation delegated to the latter. As a result, they internalized less the method value for their learning and the involvement degree decreased although they found it a motivating challenge.

Back to the results' direct analysis derived from the students' works and projects, 60% passed them in continuous evaluation, considering the three courses globally. 80% passed first call evaluation tests without resorting to the second examination call. The first call high pass rate responds to the fact that the teams always have the possibility of grade improvement in the two examination calls, so many of the groups decided to improve project deliveries implementing the teacher's partial corrections. This is a basic and recommendable criterion in the active methodology type applied. The balance between courses also shows a progression in the increase of students

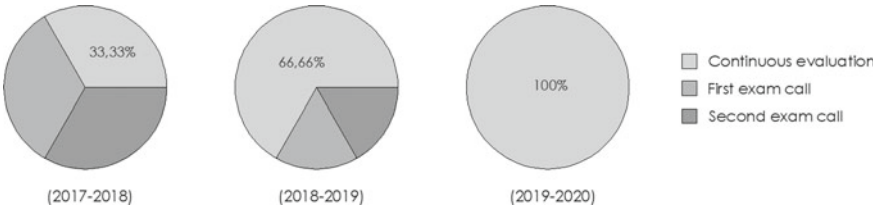

Fig. 7.7 Percentage of students with a pass rate on assignments and projects per assessment call

who passed the subject in continuous evaluation, but this time is due to the fact that the number of students enrolled was inversely decreasing, favoring the full number of passes (Fig. 7.7).

7.5 Conclusions

The architectural technician's specialization in the material and constructive heritage recognition, among other areas, in the pathological processes' identification, their causes' diagnosis and the proposal of conservation, rehabilitation and restoration actions, makes him/her a key agent of the building construction project. We have to focus this to take the work system generally adopted and transpose it to the educational field.

In the Engineering and Architecture branch of knowledge, PBL active methodology is a valid model that allows activities' organization and structure very similar to the used in the professional practice, for degrees with courses oriented to the projects' achievement on existing buildings.

Opting for a real building as mediation to facilitate the teaching activity of rehabilitation, restoration and pathology, facing hypothetical contexts of non-existent or partially imagined buildings, helps future technicians in the field to acquire a more meaningful and complete experiential learning during their university training. Access to the historic site and contact with the architectural scale of the heritage property not only allows them to learn the knowledge of a subject, but also provides them with a closer approach to the practice of architecture and prepares them to develop business practices and for their job placement. Especially when employers tend to value previous experience in a work situation.

The PBL methodology created combines the professional dimension of the elaboration of an intervention constructive project in an existing building with the skills framework and learning outcomes of the course and degree it belongs. The teaching–learning system, based on the design process of the profession, was structured from this primary core of project levels, in interrelated phases making up a sort of educational cycle open to its implementation in the study of all heritage types.

If the system design is refined and a sequential dynamic is generated, not exclusively temporary, but as a constituted network promoting cooperation and collaboration, the favorable results in continuous evaluation and first exam call increase, as well as the student satisfaction level as well as their personal and social development. Students work in interconnected groups, generating a learning community, as they share progress and results in the classroom and exchange information, promoting their socialization. Thus, they can get to perceive the multidisciplinary character and team execution of the project phases, in an environment close to the professional reality.

The work project transformation into an academic project, in this teaching experience, takes the opposite direction by facilitating the students' role applying the knowledge learned. The duty of those of us who contribute to their training will enable them to transfer their technical knowledge to their colleagues and to society. This vehicular task is not exclusive to educators and architecture professionals. It is also the responsibility of the public administrations in charge of managing the socially constructed cultural heritage to teach and enhance our architectural legacy's value, serving as an instrument to promote its preservation as a potential socioeconomic and cultural resource.

Co-responsibility in this sense does not have to stop us from reaching the highest levels in university teaching and learning process. Educational institutions and teachers must continue to train in competencies with intellectual and professional objectives, but, at the same time, with human and social values to forge great technicians committed to respond to the needs of today and tomorrow, considering yesterday's lessons. From this point of view, through historical buildings PBL, the aim is to support education as a sensitization's instrument and awareness in the heritage's protection and conservation, intensifying its significance and social responsibility. Students, trained in this way and aware of the need to educate to preserve, become a valuable channel transmitting architectural heritage's universality in the collective memory and the energy that still preserves our past legacy in the present and for the future.

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Chapter 8
Evaluating the Adaptation of a Secondary Teacher Training Programme: A Case in the Time of Pandemic

Guadalupe Trigueros-Gordillo and Cristina Ceballos-Hernández

Abstract This paper has been prompted by the detection of some needs in secondary-school teacher training, especially as a result of the COVID-19 pandemic. In response, several training accessions are made from the initial teacher training programme. First, measures are included designed to facilitate the acquisition of digital competence, especially in teaching in online environments. Communication skills are also developed. The perception of trainee teachers is obtained after they start their period of teaching practice. Both of these actions are perceived as very positive, useful, and enriching for pupils. Teachers' confidence and experience were improved when they started their teaching practice. It is suggested that both of these subjects become mandatory before teaching is begun. Improvements include new learning environments and the strengthening of practical training.

Keywords Teacher training · Secondary-school teaching · Digital teaching competence · Communication skills

8.1 Introduction

The health crisis has gone hand-in-hand with a crisis in education, where major changes have taken place in a very short period of time. Educators' visible work has enhanced their standing and earned them respect, singling them out as knowledgeable professionals, community leaders, and essential workers who maintain cohesion in communities (Hill et al., 2020). However, teachers have been subjected to a significant the level of stress and pressure (Oducado et al., 2021; Ozamiz-Etxebarria et al.,

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_8

2021; Pressley, 2021). Rapid adaptation to online environments, a frequent lack of training in the use of tools to monitor and assess students and in communication skills in these environments was the trigger of much of this stress. Prior studies indicate that educating teachers in technological innovations is a slow process, so they fail to gain the digital competence required to integrate technology into their future professional contexts (Engen, 2019). Better teacher training and greater support from their education centers and the administration are some of the measures needed to mitigate these situations. Without wishing to appear pessimistic and alarmist, the suspicion that other pandemics will arise due, among other factors, to globalization, is driving the need for universities to improve the professional competences of future graduates in the field of education, especially their digital competences and communication skills with pupils.

The preparation that teachers have received during COVID-19 has been found wanting (Looi et al., 2021). Systemic training must be designed to provide educators with the relevant skills to engage in their teaching duties (Zhang et al., 2020). In the area of initial secondary-school teacher training, modifying their training is, precisely, one of the improvements proposed in the exhaustive report by Núñez et al. (2020). This report states the importance and urgency of strengthening the training of teaching staff in the broad area of digital competences and online learning methods.

We believe that there is a need for significant experiences that improve educators' teaching competence during the initial training stage. This work presents a series of actions developed in conjunction with trainee secondary-school teachers (hereafter TT) to improve some shortcomings detected during the pandemic. We specifically aim to improve teachers' digital teaching competence and develop their communication skills in both face-to-face and online environments. The perception of the TT is obtained after they initiate their teaching practice. The context in which this study has been developed is the Master's Degree in Teacher Training for Secondary and Sixth Form Teaching, Vocational Training, and Language Teaching (Master's in Secondary Education) at the University of Seville.

8.2 Initial Training for Secondary-School Teachers and Some Shortcomings Detected

To be able to teach in Spain, secondary or high school teachers must hold a first degree in the corresponding subject area and complete a 'Master's course in Secondary Education'. Said Master's course enables prospective teachers to practice their profession while at the same time it represents the basis of their initial training. What is clear is that the knowledge and competences acquired during this preparation phase are not a strong enough or definitive basis, but they are, nonetheless, an essential component whose quality needs to be guaranteed to successfully enter into the teaching profession. This particular Master's course is taught at 46 public and 19

private universities in Spain. At the University of Seville, where this study is contextualized, there are over 450 TT, 19 different specialties, over 225 lecturers, some 80 departments involved in teaching, and 4 double Master's degree agreements.

According to a study of secondary education teachers by López and García (2021) based on the 2018 PISA report, there is a substantial gap between what practicing teachers perceive their initial training to be and what it should be in the estimation of the OECD. Over a third consider that their training for the profession does not include the requisites for teaching. In general, TT hardly have any practical knowledge of teaching when they begin their Master's degree. Studies at various universities conclude that future teachers perceive an increase in their skills level after they have completed the Master's degree course. The studies present variations in the extent to which this increase is noted but the most significant improvement is observed in the most recent study, and the training is understood to be an enriching and optimizing process that enhances their Master's degree (Manso & Martín, 2014; Sarceda-Gorgoso et al., 2020; Serrano & Pontes, 2015). Statistically significant differences can also be observed between the universities involved (Sarceda-Gorgoso et al., 2020).

Some studies indicate that training given in ICT renders the teacher training profile low in this area both for future primary school teachers (on the Primary Education Degree) and secondary-school teachers (on the Master's in Secondary Education) (Fernández-Cruz & Fernández-Díaz, 2016). However, differences from the training that they have received are observed once they start their teaching practice. The same study concludes that long-life learning in the ICT area is greater in the case of secondary-school teachers. Teachers' competence level for problem-solving in the 'Innovation and use of digital technology' competence domain is not sufficient to enable them to satisfactorily integrate ICT into schools. Following Palacios-Rodríguez and Martín-Párraga (2021) 'teachers know and use the classic technological resources and spaces but find more complex tasks such as using technology to collaborate, share, and generate knowledge more difficult in practice'. This justifies the need for centers to undertake formative actions in teachers' initial training to improve teachers' competence levels. Various initiatives have been implemented in teacher training master's degrees to develop future teachers' digital competence (Jiménez-Hernández et al., 2021; Romero-García et al., 2020). The latter authors highlight the appropriacy of training future teachers in the ability to integrate the ICT into the syllabus and their teaching, and also that secondary-school pupils should be able to duly acquire this competence themselves.

Teaching in VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) environments requires educational institutions to design and implement strategies to address uncertainty and volatility. There is a broad range of traditional skills that a teacher should possess to be able to teach. It is even more important to possess and manage them in online and semi-face-to-face environments. In this context, *inter alia*, we can point to skills in organizing content, good online communication, and even pedagogical skills in digital environments to be able to manage, handle, and teach content through an online teaching platform.

Below, we present the changes put in place in the University of Seville Master's training program to enrich and adapt the preparation of TT to the new scenario. The plan was implemented between March 2020 and June 2021 (two academic years).

8.3 Acquiring New Skills: The Emergency Programme

This work focuses on two of the groups of actions in the complementary training program that was developed. First, actions aimed at acquiring digital competences, especially digital skills related to teaching in online environments, and, second, actions directed at acquiring communication skills. Information management processes and communication skills development are strongly related to ICT use and the use of these in teaching. They are, therefore, skills that must also be developed in TT (Fig. 8.1).

8.3.1 Digital Teaching Skills Development

Digital training of the entire university student body, in general, is justified from both the academic and the professional point of view. If students also intend to work as teachers, further training is essential to allow them to actively contribute to enabling pupils at their schools to in turn acquire digital competences.

In our case, we took a Digital Teacher Training model (e.g., DIGCOMP, DigiLit, ECD-TIC, and NETS-T) as our reference for addressing the training that TT were to receive. These models serve as a guide and a reference to institutions that offer teacher training as they include the areas of competences that teachers need to master to be able to satisfactorily engage in the teaching–learning process through ICT adoption

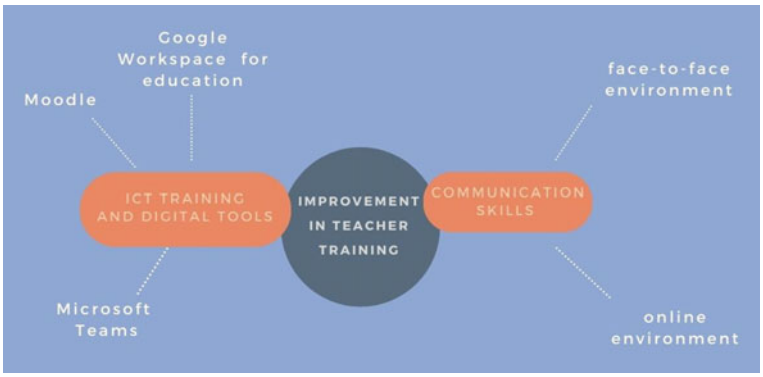

Fig. 8.1 Complementary TT training plan during the pandemic

in the classroom (Jiménez Hernández et al., 2021). Although the use of DigiLit, which specializes in giving support to secondary teacher-level ICT in the British context, was seen as valuable, we took DIGCOMP as our reference model used in earlier studies related to the initial training of future secondary-school teachers (Jiménez-Hernández et al., 2021).

Following the DIGCOMP model devised by INTEF (2017), training has been designed to improve TT digital competence. The designed theoretical-practical training gives an introduction to the incorporation of ICT into teaching and addresses the options for browsing information and conducting a search, content evaluation and selection, and the saving of data and digital content (area 1). Other areas of competence have been developed through the use of a range of digital tools to monitor students online. Special emphasis was placed on acquiring the competence to be able to create and edit digital content, multimedia content and activities and TT have been introduced to topics related to copyrights and licences (area 3).

Training in digital environments, interaction, and collaboration was also given and the options for sharing content were addressed (area 2). Lastly, work was done on a no less ambitious competence focused on identifying digital needs and resources and making decisions to select the right digital tool for the job or need. Orientation was also provided regarding problem-solving (conceptual and technical), encouraging innovation, the creative use of technology, and the need to keep one's own digital skills up-to-date (area 5).

TT have especially focused on putting these skills into practice in the framework of tutoring, nurturing cooperative work, and assessment processes. Figure 8.2 uses differently sized spheres to show how much work has been put into the different digital teaching skills in TT training. As can be inferred from the above, the only area that the training has not addressed in the digital teacher competence framework is safety (area 4).

In the past two years, the use of virtual tools or the online campus has developed from being a resource to improve performance to becoming a necessity. As a result, the use of online teaching tools with different levels of complexity and ease of use has intensified in a short space of time. One of these is Moodle. The simplicity, positive approach, and utility of this tool are factors that determine its use by students and teachers alike (Arteaga & Duarte, 2010; Escobar-Rodriguez & Monge-Lozano, 2012). Learning Management System (LMS) platforms of this type are considered essential to educational innovation. Although their use is not currently regarded as an innovation in itself, they are considered to facilitate the successful implementation of methodological innovations (evaluation by evidence, personalized learning and Flip Teaching, among others) (Fidalgo-Blanco et al., 2019). According to Badia et al. (2019), tasks, questionnaires, forums, lessons (organization of a set of teaching materials), and external tools (in the area of learning resources) are the Moodle activities most used by secondary-school teachers. This is the reason for its use in TT training. Despite everything indicating that the role of digital teaching platforms will increase in the coming years, we agree with Valeeva and Kalimullin (2021)

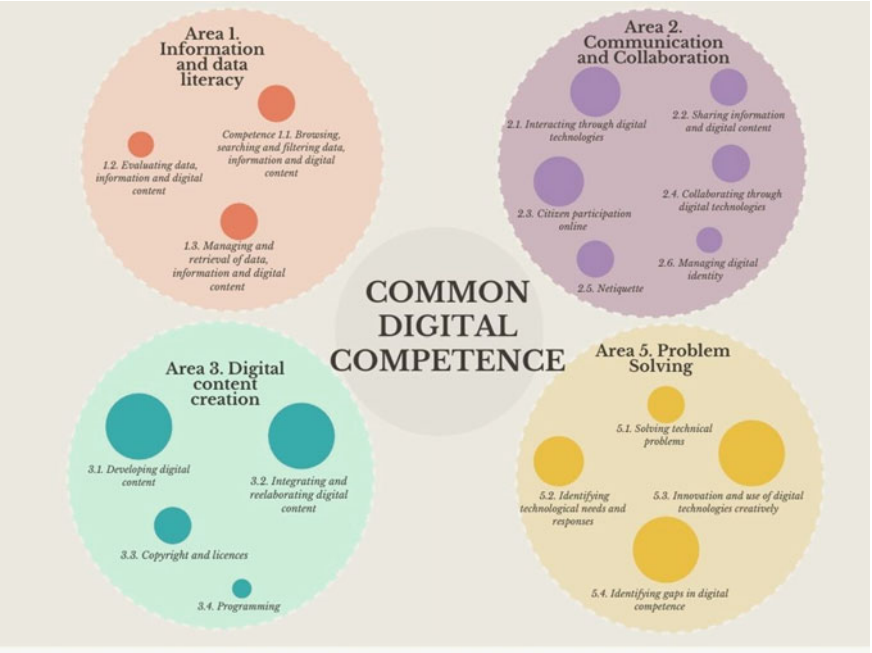

Fig. 8.2 Digital teaching competences addressed in the plan

when they state that the extent to which they are effectively applied will depend on real-life factors such as reliability, useability, data security, and the simplicity and ease of interaction between the different parties.

Despite the more intense use seen, in quite a few cases this has been the very first time that teachers have been exposed to these platforms. Along with new jargon and their relationship with active methodologies, teachers have had to learn how to use these platforms quickly in order to involve students in interactive and collaborative activities. Despite resorting to self-learning on occasion, at many other times they have sought help from their colleagues and bottom-up teacher professional learning communities (PLC) have spontaneously sprung up (Donitsa-Schmidt & Ramot, 2020). In other cases, these training experiences have been structured through courses and collaborative work between teachers who have tutored their colleagues in order to improve skills in the use of ICT tools and acquire virtual classroom skills (Llerena-Izquierdo & Ayala-Carabajo, 2021).

The competences in Fig. 8.2 were taken as the framework for the training design, called 'Digital Teaching Tools'. The training was given online using the Moodle platform. The addressed content was structured into three modules: Moodle and eLearning content creation tools, the Google Workspace for Education, and Microsoft Teams. Each of these modules included presentations, videos, exercises, self-assessment and assessment questionnaires, etc. The content was initially released according to the student's progress in his/her learning. Discussion forums were set

up and messages on the platform, and emails were used to answer any questions. To complete the tutorial action, videoconferences were held on concrete aspects of the content during the training. This training action concluded with students submitting a project completed using each of the tools. Developing these competences in different environments seeks to enable TT to develop teaching abilities in virtual environments by adapting and optimizing the resources available in different education centers to the environments used there. The duration of the training was 25 h. It began during the 2019/2020 academic year, in the middle of the lockdown, and was mandatory for all TT. The goal was to provide TT with the knowledge that would help them to more effectively and efficiently develop collaborative work with their secondary-schools' professional tutors once their virtual practice was restarted. The training was improved and expanded in the 2020/21 academic year.

8.3.2 Communication Skills Development

The instruction that secondary teachers give to their students should be comprehensive and include both personal and social areas and different social and cultural contexts. So, teachers should have solid sociological and psycho-pedagogical training, a command of social and interaction skills and suitable communication competence. Following Garijo (2020), communication techniques are one of the keystones of teaching success and are needed for:

- Communicating the message in such a way as to facilitate student understanding.
- Structuring information appropriately with a central thread that enables students to assimilate knowledge properly.
- Taking into account aspects of verbal and non-verbal communication to make it easy for the learner to understand the message.
- Taking special care of his/her voice as it is a tool of the trade.
- Knowing how to manage the stress that speaking in public produces.

Despite the importance of communication, some studies point to new teachers lacking skills and strategies to communicate in general and communicate with learners when they enter into the real world of teaching (Camus Ferri et al., 2019). The main consequence of this is that a functional communication space for learning is not generated, so these authors state the importance of actions in this line in initial teacher training.

We have been training students in communication skills for many years in our teacher training program. This is done through a cycle of workshops to improve communication skills in face-to-face environments. Given the change in the teaching scenario, since May 2020, the program has also accommodated online environments. The aim is to provide TT with effective communication techniques that enable them to better connect with their students and help them to engage in their teaching. This is especially important when they begin their teaching practice. These workshops

are high in practical content and include simulations, real presentations and expositions. Future teachers receive individualized feedback that identifies their strongpoints and areas for improvement. This training was provided online during the 2019/20 academic year with a duration of 8 h and called 'Communication skills in face-to-face and virtual environments'. Seven groups were established given the number of TT in our program. The experience indicates that the optimum group size should be 25–30 participants.

8.4 Perception of the Trainee Teachers

8.4.1 Information Gathering

The exploratory case study methodology was used. Both qualitative and quantitative data were compiled to be able to understand the reality in greater depth (Mackey & Gass, 2016). Online questionnaires were used for data collection. These instruments are considered suitable for the design of this research as they enable different types of data to be gathered (facts, behavioral information, and attitudes and opinions) (Sepulveda-Escobar & Morrison, 2020). In the following, we describe the process followed to collect the data, which were analyzed with IBM SPSS Statistics:

- re: training in 'Digital Teaching Tools'; in June 2020 (329 responses, 93.5% of participants) and April 2021 (79 responses, 65.2%). Closed questions were used in both periods for TT to rate aspects related to training (content quality, tutoring, training management, training environment, and management expectations met) on a 5-point Likert scale. TT answered open questions to rate the degree to which their digital teacher training instruction had improved, the utility of the training, its application to their future teaching (in the immediately following practice period and their future profession), positive aspects, reasons why their expectations had not been met and aspects that could be improved to conform to the needs of training, among other issues.
- re: training in 'Communication skills in face-to-face and virtual environments', in June 2020 (246 responses, 82.6% of participants). Included statements and items were rated on a 10-point Likert scale. Open questions were also included to capture TT perceptions in greater depth.

8.4.2 Perception of Digital Teaching Tools Development

This training was mandatory during the lockdown period in the 2019/20 academic year and elective in the 2020/21 academic year. During the first academic year, 352 TT took part (with 88.1% completing the course) and 265 TT during the second academic year (with a 45.7% completion rate). Both the number of TT initially enrolled on

Table 8.1 Rating of training in digital teaching tools

(On a scale of 1–5)	2019/20 (Y1)		2020/21 (Y2)	
	n	Av	n	Av
Quality of content	329	4.43	79	4.82
Tutoring	316	4.33	76	4.74
Training management	325	4.13	77	4.66
Virtual campus	327	4.44	79	4.78
Expectations met	321	96%	78	98.7%

the course and the number who completed it fell significantly when the course was elective. The number of TT was similar in both periods, which indicates the need to make this training mandatory if the intention is for certain specific competences to be acquired. After the first year, the content was expanded and the way that it was administered to the TT was modified to address needs for improvement that had been detected. In both periods, TT rated aspects related to the training. Average scores are given in Table 8.1.

The ratings given to all the items are higher for the elective course. In this case, the commitment, motivation, and interest are all higher and this can explain the higher scores. The training received in the use of digital teaching tools fully met TT expectations and, once again, was rated higher when the course was elective. TT rated the quality of the content and the tutoring by mentors positively. Other aspects related to the administration of the course (for example, inscription, group assignment, and access to information) were also rated highly. These are important issues given that communication between the university and students was entirely telematic due to the pandemic. The environment used for the training was Moodle, which the TT stated was simple and intuitive, aspects that, in the opinion of the participants, made learning easier.

After the training had finished, TT stated that their digital teaching skills had improved notably. The ability to pace the training to each TT individually was an especially salient aspect. However, one area for improvement that was singled out was the availability of all the materials from the beginning of the training, as they were released gradually as the learning progressed. This enabled TT to navigate from one resource to another as needed for their teaching practice or in line with their prior knowledge. As one TT stated:

'I think I am competent in some of the tools we worked with. It would have been useful for all the content to be made accessible together so each of us could focus on what we thought we needed' (TT121, Y1).

It is difficult to determine the content that was most useful for the TT. Some indicated Moodle and Exelearning, while others identified Google Workspace for Education. This shows that different resources are used in different schools and demonstrates the appropriacy of offering broad and varied training in all types of tools to improve students' digital teaching ability. The second year of the course included the Microsoft Teams environment, although it was used to a lesser extent

by TT during their teaching practice. This was done with a view to teachers' further skills training, as recent agreements between Microsoft and educational institutions in the region lead us to believe that this tool will be more widely used in future years. However, TT especially rate training on free software platforms, which they would be able to use of their own accord in their teaching in the future.

Regarding the methodology, TT called for the inclusion of some short practical exercises on some specific issues that might spring up in class. This is an area for improvement. As one TT stated:

'In my opinion, it might be useful to do some short exercises apart from the final exam. This would allow us to put the knowledge we get from the modules into practice. It's easy to forget some of the features that could be useful for class' (TT50, Y1).

The interactivity of the training content was also highlighted as an area for improvement. The use of multimedia materials was highly rated by TT, especially videos, which they considered essential for understanding how to use learning platforms. The flexibility that they give to the learning process was also emphasized, as they can be repeated as often as needed and at the point that is required. As was stated:

'I reckon videos are essential in this type of training for our practice teaching. You can pause, listen, go back and watch the whole process step-by-step' (TT18, Y2).

However, it was also stated that a duration of over 6–7 min was excessive. Many TT also called for it to be possible to download videos so that they could be referred back to once they were working in their teaching posts. All these issues were addressed in the second academic year and this might also be the reason for the better marks. Classes via videoconference were monothematic and had a very practical and participatory focus with TT able to ask specific questions, even related to their teaching practice in schools. The videoconferences were recorded and made available to TT, which was another aspect that they rated highly:

'Even though I had to work eight hours during the day and then go to the Master's classes in the evening, the fact that I was able to rewatch recordings of the classes and navigate through the videos at 1.5 times normal speed was wonderful and useful' (TT64, Y2).

TT on the course in both years highlighted how timely their training in these tools had been as they had been unknown to them and were extremely useful for online teaching. The utility and subsequent application of the acquired knowledge were such that TT stressed the need for this to be a mandatory part of teachers' initial training:

'This training has enabled us to adapt traditional teaching, which we had been prepared for, to the opportunities that these platforms provide. So, we have thought about it and learnt a lot about adapting to new environments and circumstances' (TT223, Y1).

As for the most suitable time for this training to be given, a large number of TT highlighted the utility of the training but also stated that it should be given before their teaching practice and not at the same time. This was especially the opinion of TT on the first course, when it was mandatory.

'It was really interesting and I really appreciate just how useful it is, but we were made to do this training at the last minute and it's a huge pity that we had to do such an interesting course at a time we were under so much stress' (TT7, Y1).

Three voluntary practical activities were also proposed apart from the questionnaires that TT had to do to test their knowledge. Not many TT did them as they had little time and an excessive amount of work to do at that point of the year, including their final project. This was stated using arguments such as the following:

'The voluntary activities are very useful for me to learn as a teacher, but I haven't got any free time to do them now when the course is being run' (TT99, Y1).

Lastly, the great interest of the TT in digital training and skills development convinced them that more time is required (course duration was estimated at 25 h) and also that the training should be broadened to take in other environments and applications.

'It was a very full, useful and dynamic course. I feel sure all the resources I have learnt will be useful for me to put in practice not only now but in the future when I'm working as a teacher' (TT37, Y2).

8.4.3 Perception of Communication Skills Development

TT rated communication skill workshops for face-to-face and online environments very highly. They also rated their utility highly, not only in the circumstances that they found themselves in, with no on-site teaching in schools, but also for their future as teachers. The overall score was 8.1 (Table 8.2). Seven trainee groups were formed, each with a mix of TT with different specialties or subjects that they would teach in the future. The instructors were the same for all the groups and the only difference between the groups was the time of day when they received their training.

The normality study using the Kolmogorov–Smirnov test for one sample (Table 8.2) indicated that the variables were not normally distributed (p-values below 0.05). Group size ranged from 27 TT in group 6 to 42 TT in group 7. The null hypothesis of equality of means was established. The non-parametric Kruskal Wallis test indicated that differences existed between the groups in the overall score ($p = 0.028$), the utility of the training that TT found for public speaking in online environments ($p = 0.004$) and the utility for defending their final project ($p = 0.041$) (Table 8.3). Figure 8.3 gives the average scores per group.

TT especially rated the focus of this training on communication skills in online environments. Many of their interventions took place in this environment, and there was a clear lack of prior knowledge in this respect. They would not have acquired these skills in a traditional training program, as they do not envisage these types of scenarios in general. However, they are currently useful and everything indicates that they will continue to be so in the future. The techniques learnt were put into practice by the trainee teachers at various times when they had to contend with speaking in public; on the one hand, during their teaching practice in secondary schools (in

Table 8.2 Perception of the utility of communication skills development in face-to-face and virtual environments and normality analysis

	Variable	N	Av	Std. Dev	Test statistic (K-S one sample)	Asymptotic significance (bilateral)
Overall rating of training	OVERALL_SCORE	246	8.10	1.882	0.231	0.000[a]
Utility of communication techniques learnt for teaching	UTIL_TEACH	246	8.23	1.907	0.196	0.000[a]
Utility of techniques learnt for speaking in public in face-to-face environments	UTIL_FACE	246	8.26	1.818	0.206	0.000[a]
Utility of techniques learnt for speaking in public in virtual environments	UTIL_ONLINE	246	8.34	1.937	0.214	0.000[a]
Application and utility of techniques learnt for defence of final project	UTIL_PROJ	246	8.22	1.853	0.202	0.000[a]

c. Lilliefors significance correction

both face-to-face and online classes), and on the other hand, to defend their end-of-Master's course project (FP), which was both face-to-face and online. The cascade effect of this training was also highly rated. Teachers can simultaneously be explicit models in the instruction that they give pupils and implicit in the latter's observation of them. TT stated their satisfaction both with the instructors' command of the subject (9.07) and the clarity of their explanations (9.15), and their willingness to clarify any doubts and answer any questions (9.28). They said that the instructors were like tutors during the practical training period as this training was linked to their teaching practice.

Table 8.3 Differences between groups in developing communication skills

Test statistics[a,b]					
	OVERALL_SCORE	UTIL_TEACH	UTIL_FACE	UTIL_ONLINE	UTIL_PROJ
Kruskal–Wallis H	12.574	8.409	8.757	17.493	11.591
Df	5	5	5	5	5
Asymptotic significance	0.028	0.135	0.119	0.004	0.041

[a]Kruskal Wallis test
[b]Grouping variable: group

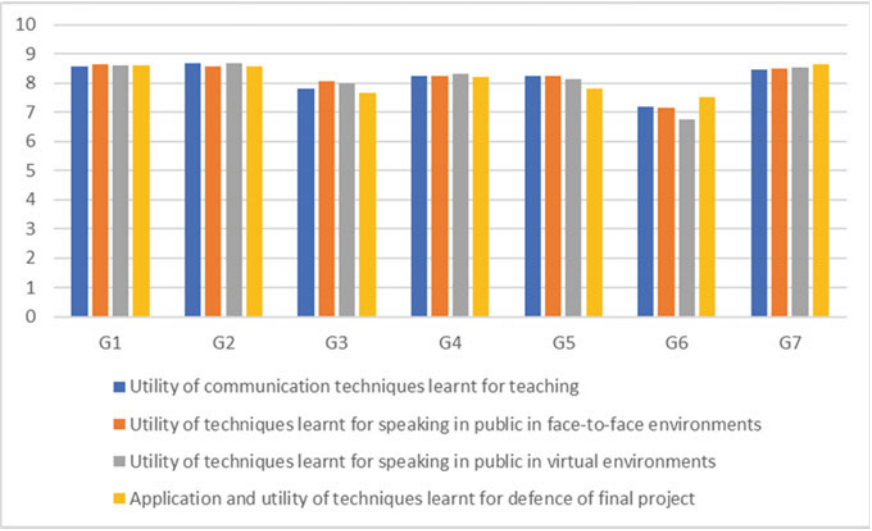

Fig. 8.3 Communication skills ratings by group

8.5 Conclusions

In the wake of the crisis in education triggered by COVID-19, there is now a greater need than ever to reflect on initial training stage teacher training for secondary-school teachers. We believe it is useful to share experiences undertaken in this regard. In our case, we have worked on two key competences: digital competence in a course on digital teaching tools for monitoring and assessing pupils, and communication skills in both face-to-face and online environments. The satisfaction that the TT have shown with this training plan is relatively high. They also highlighted its great perceived utility after taking up their in-school teaching practice posts.

As a result of their training in online tools for monitoring pupils, the incorporation of TT into schools was very positive during the lockdown period from March to May 2020. TT and secondary-school teachers came together, with the latter helping with lesson planning and real teaching. This training not only enabled the teachers of the future to become a significant auxiliary force to assist professional school tutors, but sometimes these roles were reversed. Thanks to their acquired skills, the TT designed activities and developed content that the teachers—tutors who during lockdown had to cope with an enormous work overload—were able to use in class. For example, among other content, the TT designed escape rooms, created videos, and designed questionnaires for use in online environments. All this improved their digital competences. The training was optimized for the second year by including areas for improvement that had been detected (tools used, release of content, duration of videos, *inter alia*). After the first-year students' training, collaborative work with the professional teaching practice tutor was online. After the second year, there was

practice in semi-face-to-face environments and many digital tools continued to be used, even in face-to-face situations. The improved training of TT led to cooperation being stepped up between secondary schools and the Master's course in teacher training.

Practically all the TT rated being trained in the use of these tools positively as they were unknown quantities and extremely beneficial for online teaching. Such was the utility of this training that the TT highlighted that it should form a mandatory part of teachers' initial training, have its duration increased and be done before students begin their teaching practice. They also stated that it should include multiple practical exercises, as this would enable them to become fully acquainted with the various tools used and thus continue to improve their digital competence. They also pointed out the need to include other environments and activity creation applications and other materials that they could use with their pupils online.

It is important to maintain pupils' study motivation, virtual class attendance, assimilation of the subject matter and completion of tasks in online and semi-face-to-face environments. Training in communication techniques also enabled improvements in this regard. Improving their skills in communication tools was extremely useful for TT, not only in the situation in which they found themselves, with no on-site face-to-face teaching, but also with a view to their future experience as teachers, as a result of which its inclusion in training programs is recommended. One aspect that should be highlighted in this regard is the importance of training in this competence to respond to the current inclusion of classes on public speaking in secondary education. TT must be ready to assume this professional duty.

We can conclude that TT training has been strengthened by the designed complementary training plan. Although the plan began as an emergency response in a crisis situation, it was improved during the 2020/21 academic year and is currently being perfected in 2021/22. It is evolving towards quality, well-planned teaching for future teachers.

There are evident signs that innovation in education and its transformation into more innovative learning through the use of all the resources that technology has to offer arrived in one fell swoop and is here to stay. Following Sein-Echaluce et al. (2020), innovation in education can be designed globally, applied locally and transferred to other contexts. This is the reason why, despite the design and application of a teaching innovation being shaped by many factors, we consider that these measures may serve as an inspiration for other teacher training Master's courses.

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Chapter 9
Error-Controlled Exercise Training and Its Impact on Learning

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Abstract This chapter extends a previous experience of educational innovation carried out at the E.T.S.I. Minas y Energía of the Universidad Politécnica de Madrid, deepening the analysis of the impact that training exercises with controlled errors has on learning. Based on the results obtained in the marks of the evaluable tests in three different subjects, we analyze the impact on learning of a study tool that consists of proposing to students to locate the controlled errors appearing in different exercises and problems. To determine the usefulness of the training tool with controlled errors

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_9

in student learning, satisfaction surveys were carried out. The collected information evidences the high degree of satisfaction that students show with this learning methodology, highlighting the feeling of students regarding better learning thanks to its use during study. With this new research presented here, the results previously obtained are validated and the positive impact of this methodology on learning is confirmed. In addition, the achievement of a similar degree of satisfaction in very different subjects and in groups of students from different academic years, demonstrates its versatility, making it a didactic resource applicable in different learning contexts.

Keywords Learning improvement · Error-controlled training · Results distribution · Learning tool

9.1 Introduction

Constructivism can be defined as the set of conceptions that provides a solid basis to understand that learning is not an exclusive phenomenon in school and higher education, but is produced throughout people's lives in their means of socialization (Ordoñez, 2004). The theory states that learners construct knowledge instead of taking information in a passive way. It is a fact that making mistakes is inherent to human beings, since we are born, during childhood and adolescence together with the different stages of compulsory and university education, and throughout our professional life. The impact that these mistakes have on each individual can be of a very diverse nature from not detecting the error and committing it repeatedly to detecting it from the very first moment and trying not to make the same mistake again. Every mistake made by a person is a great learning opportunity, as several authors have reported in their works (Briceño, 2009; Manrique & Puente, 1999). It is, therefore, reasonable to use an error-based learning tool to enhance learning. Previous literature analyzes the methodology of learning by mistakes together with positive and negative reinforcement (Chialvo & Bak, 1999), peer interaction (Pinkerton, 2005), and quiz corrections (Henderson & Harper, 2009) among others, and found out that in order to reduce the number of mistakes, it is needed to learn from them.

When students study for an assessment test, it is common for them to have doubts that, at the time they appear, they cannot consult the lecturer. The availability of tools or resources that allow them to independently solve these doubts (Amez et al., 2019; Castells et al., 2019) was probed to be useful. In this context, asynchronous resources can be very useful, as they provide students greater flexibility. These asynchronous resources are usually supported by ICT (Information and Communication Technologies) tools, which currently makes them more attractive to students. Among the asynchronous resources, very useful tools can be found such as educational videos, which aim to benefit from the major advantages provided by face-to-face tutorials or the Frequently Asked Questions—FAQ (López et al., 2012). Thus, students are able to solve the doubts generated during the study by themselves, improving learning

results in heterogeneous groups, and promoting autonomous learning (Failed, 2018). However, the use of videos as a means of reinforcing the study implies a limitation, which is the evidence collection. This fact makes it difficult to analyze the impact on learning, and therefore, does not allow correct implementation of educational innovation as the true effect cannot be measured (Amez et al., 2019; Castells et al., 2019).

However, asynchronous digital resources are not just limited to videos or teaching materials. Students should have access to other tools that help optimize the time they dedicate to independent and self-study. One of these tools consists of training with banks of questions containing controlled errors, either through self-assessment questionnaires or through tests that students take during the course. Students usually memorize and learn by heart contents, without really understanding their meaning, and most of what is memorized are quickly forgotten after the exams. However, when controlled errors are included in different types of questions, students are forced to reflect on their knowledge to detect and solve the errors. In VanLehn CASCADE theory, (VanLehn, 1999) argues how mistakes can make people reflect to reach a deeper understanding, which is known as impasse-driven learning.

Several authors (Moreira, 2005; Norris & Ennis, 1989; Zunzarren, 2012) have reflected on the use of errors as a tool to improve learning. Most of them emphasize the relevance of fostering critical thinking and the idea that the human being develops as a person as he rectifies the various mistakes that he is committing in the different aspects of his life (Principle of Learning by the Error). Applying this principle to the educational context, the student is able to develop the critical spirit that allows him to detect errors, while he expands the possibilities of achieving excellence in learning. Those skills do not only apply to education, but will be extrapolated also to his professional future. In addition, the use of errors in training can facilitate the transfer of training, understanding as such the generalization of learning, which leads to a more successful performance when the transfer consists of applying the acquired skill to new problems (Annett & Sparrow, 1986).

Errors are a natural consequence of the strategies of searching for the correct answer among a set of possibilities, eliminating the incorrect alternatives (Ivancic & Hesketh, 1995). Thereupon, (Siegler, 2002) states that if the probability of choosing an incorrect answer is reduced, the probability of choosing the correct answer increases. It means that, by applying these search strategies, students are able to detect errors in the proposed answers and discard those choices, thus increasing their chances of improving the results. Siegler (2002) also points out that encouraging students to justify why an answer is correct or incorrect leads to more flexible knowledge than if only the correct solution is explained. This chapter analyzes the impact of learning the methodology developed in Arévalo-Lomas et al. (2022). Firstly, a selection of the most common mistakes and errors made by students was used. These were included in a controlled way in questionnaires and training exercises, and, in some cases, they were also implemented in the evaluation test exercises. These errors have a direct impact on the effectiveness of transfer as they increase attention, allow correcting previous mental models, and recovering previous examples. Therefore, one way to make the students more conscious of what they are learning is to get

them to detect the controlled errors introduced by the lecturers in the training exercises. The methodology benefits from the "positive side" of the error, removing its possible negative effects, especially on an emotional level, and turning them into fundamental pieces of learning as a tool that allows the extraction of more precise and lasting information, applicable to future problems.

Secondly, a series of activities were carried out with exercises based on error detection within three subjects in the E.T.S.I. Minas y Energía of the Universidad Politécnica de Madrid consists of training (preparation exercises) for the evaluation tests with exercises that included controlled errors. It was analyzed how the implementation of these types of exercises affects learning and if this methodology could become a tool commonly used in other subjects.

Finally, the methodology was applied on three different subjects, Chemistry, Graphic Expression, and Business Management, using multiple choice questions with four possible options and a limited response time. The evaluation system on those subjects was carried out under two different approaches: evaluation with controlled-error exercises (Graphic Expression) and traditional exercises without controlled errors (Chemistry and Business Management). In addition, regarding Graphic Expression, obtained results distribution was compared to data from previous courses in which training with errors was not used. In order to assess the usefulness of the methodology, satisfaction surveys were conducted among the students of these subjects. Some of the most relevant conclusions are presented in this chapter.

Historically, the distribution of the results in terms of qualification in a subject has been considered to tend to be a normal distribution, although it is true that, in the last decades, some authors have pointed out the error that is committed in this type of distributions by not incorporating asymmetry factors (Arthurs et al., 2019; Fendler & Muzaffar, 2008; O'Dea et al., 2018). The assumption of a normal distribution prevents the correct identification of the different groups in which the students could be classified, and therefore, false equity between them is presumed. If instead of assuming this behavior, a distribution analysis is carried out, it is possible to reflect on the convenience or not of classifying students in the scope of the European Higher Education Area (EHEA) based on competency-based learning.

9.2 Context

The pursuit of methodologies to improve student learning is one of the lecturers' tasks and the development of these methodologies is becoming, every day more, a source of research. The memorization of the contents explained during lessons by the lecturer or the information available to students by other means is often the usual technique that students use in order to pass the evaluation tests. The effect that making mistakes produces on humans is well known. Making mistakes has traditionally been perceived as facilitating learning, as once a mistake is made, it is less likely to do it again. In other words, in the same situation, we will be able to identify the error previously made. In regulated studies, this idea can be extrapolated, in such a way

that the error made entails learning about the content in which the error has been made.

The main goal of this methodology was to enable a new tool that eases the teaching process to improve the student's level of learning. With the use of exercises that include controlled errors in self-study, reflective learning is encouraged in the student, based on critical thinking, which will accompany him after his education in all areas of his life, including his professional career. The main advantage of reflective learning is that, unlike learning based on memorization, students retain more time for the learnt knowledge, since, in order to reach this type of learning, the student has faced reflections on the concepts at a higher comprehensive level than that which would correspond to the memorization of contents. After the learning process is based on controlled errors, evaluation tests are carried out, which may or may not contain controlled errors, the results of which confirm learning improvement.

The methodology was implemented during the 2020/2021 academic year in the three aforementioned subjects of the Engineering Degrees (Degree in Mining Technology Engineering—GITM and Degree in Energy Engineering—GIE) taught at the E.T.S.I. Minas y Energía of the Universidad Politécnica de Madrid. Having verified the improvement in the students' marks after the use of the methodology based on the inclusion of controlled errors in the exercises (Arévalo-Lomas et al., 2022), the research focuses here on verifying the students' satisfaction and their perception of their learning process. In addition, a validation of the methodology has been carried out by applying it again during the 2021/2022 academic year in the same way. Errors that have been introduced in the exercises can be classified into two types: calculation errors (implemented in the Chemistry subject) and comprehension errors (implemented in the Business Management, Graphic Expression, and Chemistry subjects). On the one hand, in the calculation errors, students face solved numerical exercises whose answer choices contain errors in the formulas or equations applied. On the other hand, comprehension errors consist, in the Business Management and Chemistry subjects, of theoretical statements among which some answers are introduced that contain a controlled error derived from a poor understanding or misunderstanding of the theoretical–practical concepts in which the problem is based, as well as numerical exercises solved using the wrong procedure that students have to detect. Finally, in the case of the subject of Graphic Expression, given its syllabus and methodology, comprehension errors are presented graphically, through plans, views, and representations that may contain controlled errors or not, and that students have to be able to identify.

One of the key steps for the correct deployment of the methodology is found in the meticulous compilation of the most frequent errors made by the students and the subsequent appropriate design of the questions that contain controlled errors. This aspect improves the students' perception of this methodology because they identify errors that are familiar to them. For each of the subjects participating in this study, the most common errors made by the students were collected from previous exams, exercises, and tests, and from there, questions related to those errors were designed that were added to an extensive questions database with controlled errors. In the case study, the experience of the lecturers during several courses has served to identify the

most common failures of the students in each of the subjects, such as the errors made when calculating scales (Graphic Expression) or in the unit changes (Chemistry).

For each of the frequent errors made by the students, a large number of questions were designed. The students had access to them in the form of self-evaluation questionnaires through the Moodle platform, as a training tool for the evaluation tests. The system generates, from the question database, random questionnaires, so that the students can rehearse as many times as they consider necessary without repeating the questions. These question databases are being expanded each year, so that the probability of the questions being repeated is significantly reduced, thus avoiding those questions being learnt by heart, since, for some of the subjects, questions with controlled errors are included in the evaluation tests. This methodology can be applied to subjects of a very diverse nature in the university educational environment, or any other educational institution, as the training and practicing with controlled errors can be performed with either theoretical or practical content.

9.3 Description

After collecting the most frequent errors and generating question banks on the Moodle platform, the study was divided into two main phases for each of the three participating subjects, before the satisfaction surveys. The first phase, or "training" phase, had as its main objective to encourage autonomous work by students through the completion of Moodle questionnaires. These questionnaires, as mentioned above, were generated from banks of random questions which include exercises with errors designed specifically for this methodology. In this way, students were trained not only in solving exercises for the evaluation tests, but also in detecting and correcting the most common errors in each subject. This forces them to focus on those contents that are historically more difficult for them to understand. In addition, the questionnaires themselves are an excellent study tool that can be accessed for an unlimited number of times. This type of questionnaire was not evaluated as it is a training phase and is designed as a study tool. After this first phase, the methodology proposed a second phase or evaluation phase whose aim was to assess the skills acquired by the students with questions with or without controlled errors in the responses. This phase was particularly important as it allows for the collection of evidence and subsequent analysis of the methodology applied. Each of the subjects involved designs the evaluation test in accordance with its methodologies and content.

The questions' elaboration was a critical aspect, since their design must be conducive to the detection of errors by the students and must focus on common errors detected in the subjects involved. Therefore, a thorough process of analysis and selection was followed in order to optimize their impact on student learning. For the collection of errors, first of all, the evaluation tests carried out historically were reviewed. As a result, a database was generated in which the most frequent errors detected in the analysis were compiled. In order to give greater depth to the analysis and to generate the database with the most significant errors, it was considered

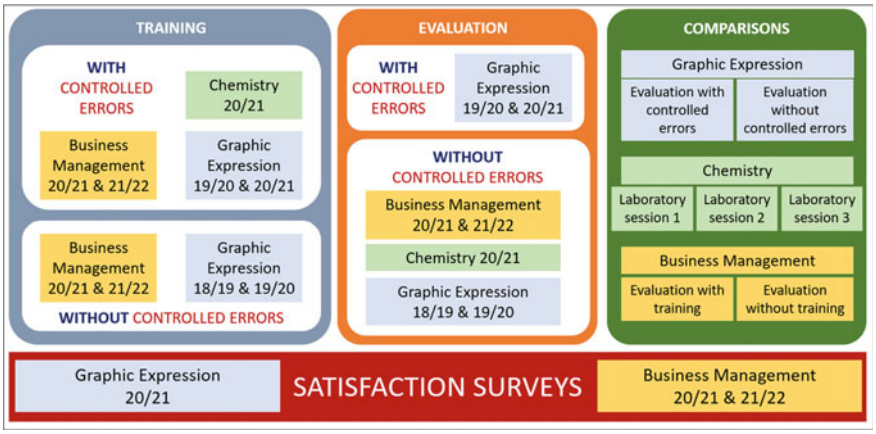

Fig. 9.1 Summary diagram of the different phases of the study (Modified from Arévalo-Lomas et al. (2022))

essential to have the expertise of the lecturers. On the basis of the selected errors, the questions that would later feed the question banks in the Moodle questionnaires for each of the subjects were designed. The questionnaires contained questions of a similar nature to those included in previous years, and some questions containing controlled errors were added. In addition, for each subject, different training modes were programmed for the students to practice for the exam. Figure 9.1 shows an outline of the data used for the analysis carried out (training and evaluation phases), the comparisons of results, and the satisfaction surveys conducted at the end of the process.

A brief description of the type of exercises that were carried out in the different subjects considered for this analysis is provided below.

Chemistry: Online questionnaires with 4 possible answers for each question were conducted through the Moodle platform during the theoretical classes so that the marks of each student could be easily downloaded. The exercises consisted of problems similar to those done in the laboratory exams and lessons, as well as theoretical and practical questions as described below. It was decided to apply this methodology to improve the marks for the laboratory sessions, as in recent years they have been quite low, and as there is a lab session for each subject block of the course with its corresponding exam (in this case they were carried out for chemical kinetics, chemical equilibria, and acid–base equilibria), it is the best way for the students to keep the course up to date and to be able to carry out the continuous evaluation. Therefore, these questionnaires served as training, not counting toward the marks in the final evaluation, and were completed by the lecturer at the end of the time given for their completion, focusing on the most important concepts that had not been made clear. For this reason, these questionnaires were carried out in the classroom before the laboratory session, and the exercises were selected because of the unsatisfactory results obtained by the students on these problems, so that we

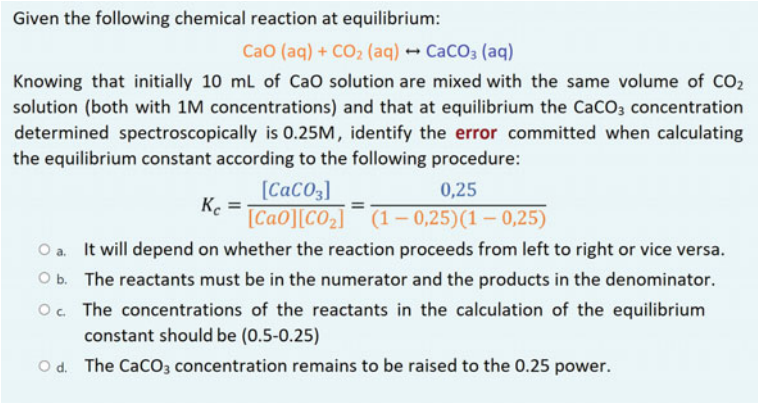

Fig. 9.2 Sample question used to apply the methodology to the Chemical Equilibrium laboratory

could check whether there was an improvement in the learning of these concepts based on the marks obtained in the exams. The exercises corresponded to one of the following typologies:

- Solved numerical problems, which are presented to the students with the different calculations up to the final solution. Students must identify a controlled error throughout the given solution.
- Direct calculation problem presented with the different answer options developed. Out of the 4 options, 3 are procedures that students often apply incorrectly.
- Statements with concepts of a theoretical–practical nature in which students often have difficulties. One of these statements contains a controlled error that students must detect.

Figure 9.2 shows an example of one of the questions with controlled errors proposed in the Chemical Equilibrium laboratory.

Business Management: A bank of theoretical test-type questions was created for this subject. The questions were chosen based on the experience of previous courses. Students often have trouble learning these concepts and make frequent mistakes when using them. With this bank of questions, different questionnaires were randomly generated on the Moodle platform. In this way, the students had enough material to carry out as many training sessions as they needed, all the questionnaires being different from each other. In each attempt, ten questions with four possible answers appeared. Three of the answers were statements that may or may not include an error, the fourth answer was always the same "all three answers above are correct". The students had to answer quickly among the four answer options, marking the answer that included an error in the statement or, in case none of the three answers contained an error, they had to mark the fourth option, which indicated that none of the other three answers contained errors. As an example, one of the questions created for the training questionnaires for this subject is shown in Fig. 9.3. Once the tool had been created, it was made available to students seven days before the date of the

T7-EEA2- If we are comparing two alternatives for an investment project with similar conditions and risk, and we have obtained for option A an NPV=80,000 € and for option B an NPV=100,000 €, both calculated with an equal discount rate. Indicate which of the following statements contains an error:

a. As both options have an NPV > 0, both options are interesting because they recover more money than has been invested.
b. Using the NPV as the only selection criterion we should choose option B (the one with the highest NPV).
c. The discount rate used to calculate the NPV should be different for each alternative.
d. All three answers above are correct.

Fig. 9.3 Sample question used to apply the methodology in Business Management subject

continuous evaluation test, so that it could be used by students as a self-evaluation tool after they had begun to study for the evaluation test. It should be noted that the evaluation test also consisted of a Moodle questionnaire, but in this case, it was a traditional questionnaire, i.e., the answers did not include controlled errors, but the answer that had to be marked was the one that contained a correct statement. This was done in this way so that the test with the training tool with controlled errors would not be used to learn how to do a specific test by repetition but would serve as a means of review and understanding of the contents that would be evaluated in a different way (traditional questionnaire).

Graphic Expression: In the proposed methodology, the questions for this subject were adapted for each of the thematic blocks. Databases were created for each block and subdivided into groups according to the themes of the block. Thus, in the Visualization block, the 3 views of a given part and its projection were presented. The students had to locate in which view an edge was missing or extra. A base was created for Isometric Projection and another one for Cavalier Projection from which an equal number of questions were chosen at random. In the Dimensioned Plans block, a small area of a solved map was presented and students had to answer whether it was well solved or contained errors. The aim was to ensure fairness when designing a personalized questionnaire for each student. Figure 9.4 shows two sample questions from among those proposed in Graphic Expression

All evaluation questionnaires had parallel training questionnaires, with similar but different questions, to avoid the disadvantage of facing a newly designed exam.

To analyze the results, a series of comparisons were made with the data available within the different subjects. As a final phase of the study, and in order to check whether the impact had been positive, the methodology included student satisfaction surveys. The surveys were opened to all students, both those who had used the tool and those who had not, with a common question asking how many classes they had attended, choosing between “none”, “less than 50%”, “approximately 50%”, “more than 50%” or “all”. Students who had not used the tool were asked why they had not used it and whether they believed, if they had used it, they would have obtained a higher, lower or the same marks as they had obtained in the evaluation test. The students who had used the error-controlled training were asked how many times they had used the tool before the evaluation test, and whether they thought that by practicing with this tool they had obtained a better, worse or equal marks than if they

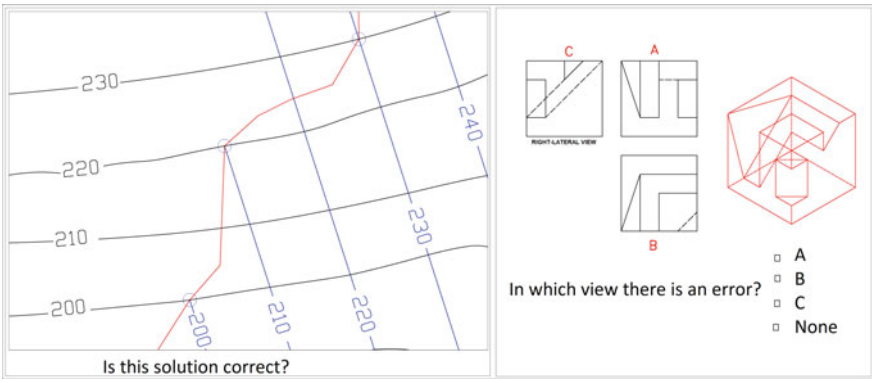

Fig. 9.4 Sample of Graphic Expression question: visualization block (left) and dimensioned plans block (right)

had not practiced, and they were asked to indicate how practicing with this tool had helped them.

9.4 Results

The obtained results from the different comparisons carried out within the subjects considered and the analysis of the satisfaction surveys and the impact of the methodology on learning are presented below.

Chemistry: In this subject, the methodology was applied by means of error-controlled exercises before three laboratory lessons (students were free to decide whether to employ or not this didactic resource). After the students performed the experimental activities, they conducted an evaluation test to assess the degree of achievement of the learning goals. In the first two lab sessions, approximately 20% of the students employed this learning tool, while only about 10% were trained for the third one. For the first lab session, no statistically significant differences were observed in the marks of the students who have trained and those who have not. However, in the last 2 sessions, the students who have performed the training exercises have subsequently obtained higher marks (p-value < 0.1). Figure 9.5 shows the violin plots for all three laboratory sessions divided into two groups: without training and with training. In violin plots, the inner band represents the first and third quartile together with the median, represented as a white dot. The remaining dots represent each individual result, showing that most of the students did not follow the training methodology. From the plot, it can be noticed that the "without training" group shows a bimodal distribution, while the "with training" group fits more a normal distribution. Bimodal distribution shows that students that did not follow the training divide around mark 3, and marks distribute similar in both directions. On the

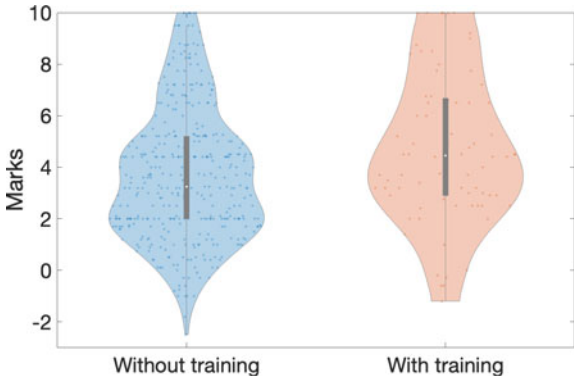

Fig. 9.5 Chemistry marks in laboratory tests according to error-controlled exercises training

other hand, students that followed the training methodology presented marks normal distributed where most of the marks are in the range between 2 and 6 points.

Furthermore, when comparing marks for each laboratory session, it was noticed that over the course (as the complexity of the theoretical content increases), there is a drop in the average test marks. This decrease was more noticeable in those students who have not trained. Therefore, it could be concluded that a low percentage of students decide to study with complementary material, either due to lack of interest or to the large volume of didactic resources available. Moreover, as this is not a task that counts for their final marks, they may not pay much attention to its correct resolution, and only a slight improvement is observed in the students who continued with the use of the tool. Furthermore, as this is a voluntary activity, when evaluating the results, the fact that the use of this and other resources is more frequent among those students who are more responsible and applied, and therefore, with better results, should be taken into account. This fact shows that in the first-year students, the main motivating factor is the improvement of the marks through the realization of different didactic activities, even more than the improvement of the acquisition of competences related to the subject.

Business Management: In this subject, students who had the error-controlled training questionnaires available could use them unlimitedly for the preparation of the evaluation questionnaire since, at each attempt, the training questionnaire was different from the previous one. The group of students who could use this tool consisted of a total of 74 students, of whom 80% (59 students) used it with varying frequency (between 1 and 11 times), therefore, 20% did not use the tool, although it was available to them (no training). The results were divided into three categories: students who completed between 1 and 4 training questionnaires with controlled errors before the evaluation test (little training) corresponding to 42% of the students, those who completed 5 or more rehearsals (much training) composed of 38% of the students, and those who did not perform training, although they had it available (no training) which, as indicated above, was 20% of the students.

The results of the marks obtained by each student in the evaluation questionnaire that took place afterward are represented in Fig. 9.6, grouping them in each of the

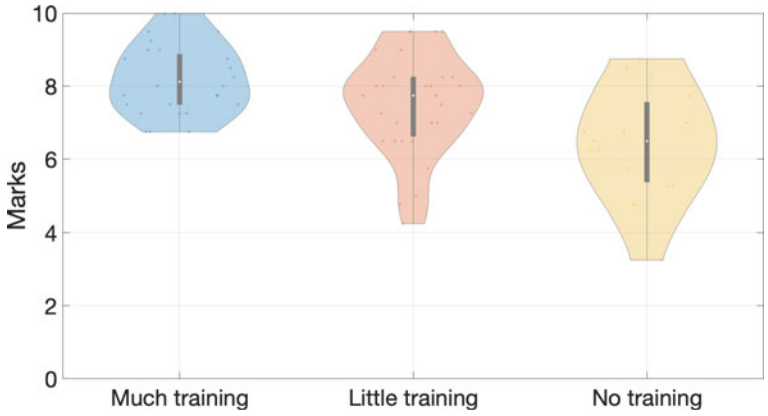

Fig. 9.6 Marks distribution in Business Management tests according to the training level

three categories indicated, i.e., according to their level of training. The students with the highest marks are also those who have performed the most training sessions before the evaluation questionnaire. But, in addition, comparing the mean marks of the three categories, it was found that there is a statistically significant difference with a confidence level of 95%. These results showed that the students who used this resource not only obtained better results, but also the results improved the more they used the tool.

If we analyze the relationship between the number of test questionnaires completed and the marks obtained, we find that there is no linear correlation between the two variables; however, there is a relationship between the marks obtained and the three categories (no training, little training, and much training), with the students who used this resource the most often generally obtaining the best marks in the evaluated questionnaire. The results are shown in Fig. 9.6, where a violin plot has been used to plot mark densities together with each individual data (represented as points). Again, the inner band represents the first and third quartile together with the median. The more compact the shape is, the less dispersion the results present, and a more uniform distribution is found. Students with much training presented more homogeneous results, as the marks are located in a smaller range than little or no training students.

A comparison was also made between the marks obtained by the students who had access to the tool for conducting training questionnaires and the marks of two groups of students from the previous course who did not have access to the tool because the innovation had not yet been introduced. One of the groups without access to the tool corresponds to students of the same degree (GITM), and the other group is from another degree (GIE). Figure 9.7 shows that in the cases in which the training tool was not available, the distribution of the marks in both degrees is practically the same, but a difference can be seen in the distribution of the marks in the degree that had

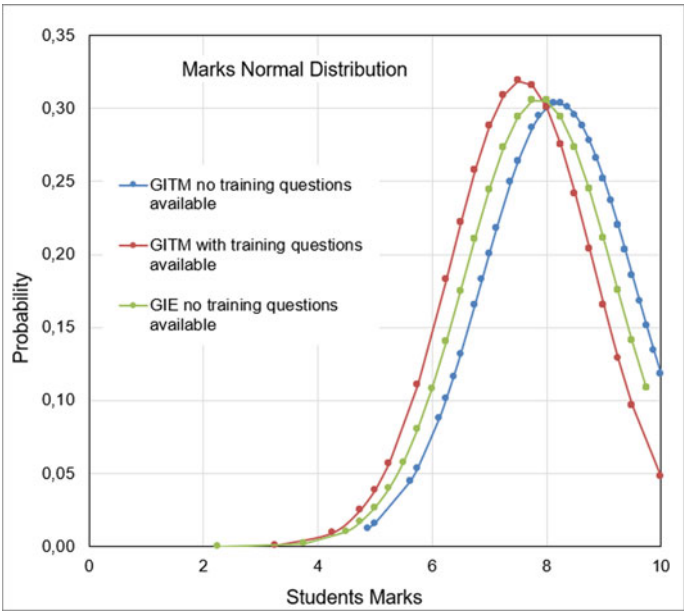

Fig. 9.7 Distribution of final marks in Business Management in both grades, differentiating between the results of students who had access to the training questions and those who did not

the training resource available, showing that the distribution is more homogeneous in the group of students who had the test questionnaires (Fig. 9.7).

To validate the methodology in the Business Management subject, the results obtained in the 2020/2021 academic year were compared with those obtained in the 2021/2022 academic year, in which the new methodology was applied to all the students of the Business Management subject, separated into two different groups, one in the first semester (GIE: Sept.–Dec. 2021) and the other in the second semester (GITM: Jan.–May 2022). Students from both groups had access to error-controlled training.

In this study, the group of students who could use this tool consisted of a total of 185 students (130 students from GIE and 55 students from GITM), of whom 80% (104 + 44 students) used it with varying frequency (between 1 and 16 times). The results were divided, as in the course before, into three categories: students who completed between 1 and 4 training questionnaires with controlled errors before the evaluation test (little training), those who completed 5 or more rehearsals (much training), and those who did not perform training, although they had it available (no training). The results of GIE are 36%, 52%, and 12%, respectively (compared to the results obtained in the previous group, there is an increase in the percentage of students who use it a lot, and a slight decrease in the percentage who do not use it at all). The results obtained for GITM are 23%, 69%, and 8%, respectively, showing a greater increase in the percentage of students who use it many times and a marked

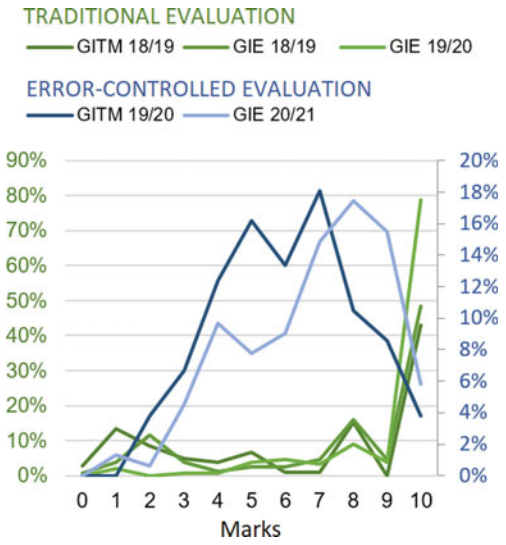

Fig. 9.8 Distribution of marks in the Graphic Expression tests for two degrees (GIE and GITM) in various academic years: without applying the methodology (green) and applying it (blue)

decrease in the percentage of students who do not use it. This shows a growing interest in using the tool for its positive impact on learning.

Graphic Expression: This subject was a pioneer in the use of this type of tool. Therefore, it was possible to use data from previous years and compare the traditional assessment with the evaluation with controlled errors. In total, 425 students took the traditional evaluation and 232 students the exam with controlled errors. The graph in Fig. 9.8 shows the absolute frequencies of the marks obtained and it can be seen that the marks were higher in the exams without errors and the ranking of the marks is less skewed when the evaluation includes controlled errors.

9.4.1 Satisfaction Surveys

After the evaluation questionnaires, satisfaction surveys were conducted on the subjects of Business Management (2020/2021 and 2021/2022) and Graphic Expression (2020/2021) for different students groups.

If we focus on the data obtained in the subject of Business Management, in the academic year 2020/2021, the survey was open to all the students who had the possibility of using the training tool (as indicated above, 74 students) to know their opinion about it and to obtain qualitative information about the resource. 60 students (82% of the total) responded to the survey. Of the students who answered the survey, 12% did not use the training questionnaires because they preferred to spend more time studying the traditional way (57%) or due to lack of time (29%), but most of them think that if they had used this tool available to them, they would have obtained a higher mark in the evaluated test than the one obtained (57% think this way). It is

worth noting that students who have not used the tool are also the ones who mostly attend less classes (72% attended less than half of the classes).

Of the students who responded to the survey and who had used the training tool (88%), had used the resource between 1 and 11 times. These students mostly attended the class (79% of them attended half or more of the classes) and believe that they scored higher on the evaluation test than if they had not practiced with the tool (87%). In addition, they were asked how using this tool had helped them (they could indicate several different responses) and the four options with the highest response percentages were that it helped them to better fix the concepts already studied (83% of them think so), that it helped them to learn more about the syllabus (50%), that it helped them to learn how to do the evaluable questionnaire (36%), and that it helped them study in a different way (32%).

When asked if they thought that it had helped them practice with questionnaires in which they could detect errors, that is, with a different way of asking questions than in the evaluation questionnaire, 80% responded that it had helped them to reason more. However, the remaining 10% indicated that they believed that this difference had not affected the result, and the remaining 10% thought that this difference, in the way of asking questions between the test questionnaire (detecting the option containing an error) and the evaluation questionnaire (detecting the correct option), had caused them to become confused.

Of the total number of students who responded in the academic year 2020/2021 (60 students), the vast majority (88%) felt that the method was very useful, while only 7% preferred the traditional method (Fig. 9.9a).

In the academic year 2021/2022, the student satisfaction survey was carried out once again, obtaining similar opinions to those obtained in the results of the previous year, which corroborate the high degree of satisfaction among the students. Specifically, of the total number of students who answered the survey for the subject of Business Management in the 2021/2022 academic year (104 in the first semester and 44 in the second semester), the majority of them (85% and 84% respectively) thought it was a very useful method, while only 6% and 16% preferred the traditional method. In the first semester, the remaining 9% did not use it due to lack of time (Fig. 9.9c, d).

All these results are practically the same as those obtained in the subject of Graphic Expression in the academic year 2020/2021 (Fig. 9.9b). The survey asked them whether they had used the error-controlled training prior to the traditional exercises, and what their views were on the usefulness of the method.

Regarding the results of the surveys conducted on both subjects, most of the students found useful the method of training with controlled-error exercises.

9.5 Discussion

The European Higher Education Framework is based on the acquisition of competencies and learning outcomes by the student when passing the subjects. Therefore,

Fig. 9.9 Results obtained in satisfaction surveys carried out on the subject of Business Management (**a** GITM 20/21, **c** GIE 21/22, and **d** GITM 21/22) and Graphic Expression (**b** GIE 20/21)

the lecturer must ask himself what marks a student must obtain within an evaluation system to be able to assume that he has achieved a certain learning outcome that leads to the acquisition of one or more competences. In the case that we are evaluating certain skills, whose ability could be acquired over time from a minimum level of performance, then the evaluation system should discriminate as many increments of achievement as possible in order to establish a minimum threshold of attainment of the learning outcome. For example, the student is able to solve 70% of the chemistry problems related to Kinetics, Equilibrium, and Acid–base so he will be able to increase his skills in the future in case he has to develop this knowledge in higher subjects or during his working life. The application of training through error-controlled exercises aims to improve and facilitate the acquisition of these skills. The application of this methodology has been adapted to the particular characteristics of each subject, showing different results in each of them.

The results presented in Fig. 9.8 show a clear improvement in the classification of students' marks when applying an evaluation system based on the identification of errors, this improvement being understood as the reduction of Skewness. According to this, the quick tests with controlled errors allow discriminating with a higher level of precision the students' ability to detect errors in the exercise solution. If it is compared to the traditional evaluation methodology, it can be observed how the approach to a single problem classifies students in a quasi-binary way: the student either knows or does not know how to solve the whole problem. In view of these

results, lecturers can consider this dichotomy in the design of their evaluation system: What is more convenient, to classify students into different degrees of ability and speed in solving an exercise or to discriminate between those students who are able to solve an exercise completely regardless of the speed of response?

According to the results in Fig. 9.8, the teaching and evaluation process in Graphic Expression obtained a distribution of marks very biased toward high marks, showing a large proportion of students obtaining the maximum mark. Does this mean that the traditional evaluation system is not capable of discriminating with a sufficient definition of the level of achievement of the learning outcomes in a subject? This would certainly not be the case. Also, in Fig. 9.8, it can be seen how there are students classified in other mark ranges, so the evaluation system is capable of making that discrimination. In fact, the distribution of results would imply that a high percentage of students evaluated have managed to obtain 100% of the learning outcomes set out in the subject. This is why, despite obtaining a more homogeneous distribution of marks, this improvement may be related to the speed and rapidity of obtaining a solution, not to the achievement of the learning goal.

This is not the case for the Business Management subject; the graphs in Fig. 9.7 show that there is no significant change in the classification of marks between students who had access to the tool and those who did not. On the contrary, there was an improvement in the achievement of learning outcomes to the extent that the use of error-controlled training increased (Fig. 9.6). Furthermore, the use of this methodology reduced the dispersion between marks, which means that differences between students decreased and more uniform results were obtained. The students who did more training were more successful in applying what they learned in the training to solve the test problems, as the median increased together with the student's training. The use of the training tool requires a greater degree of attention and dedication time by the student, which at first sight would be considered as a slowdown in the acquisition of this knowledge. However, this is only a part of it, since for these same reasons, in addition to knowledge, they develop skills that will be useful in future subjects. It would be interesting to monitor the groups that have received the training with errors and those that have not, in order to verify the differential impact that occurs in both groups in the acquisition and transfer of skills.

In the case of the results obtained for the Chemistry subject (Fig. 9.5), the most relevant information obtained was the different distribution when comparing students with and without training. While students with training presented a marks normal distribution, the students mark without it approached bimodal distribution, with low mode values. Again, it is noticed that training can homogenize students' marks, and produce normal distributions and less dispersion, and therefore, differences between students. Moreover, it was noticed that the improvement in the use of error-controlled training has not produced an apparent improvement in the results. This could be explained by several factors unrelated to the method. On the one hand, the students used this didactic tool voluntarily, without any incentive to use it through marks. On the other hand, the tests were carried out telematically, so it could be the case that the students filled them in without paying the same attention to them as they would have done in person under the supervision of a lecturer. These considerations highlight

the importance of the student profile in the use of didactic materials, being students in the last years of bachelor's and master's degrees are more responsible in terms of dedication and study than the first-year students, whose main objective is usually oriented to the acquisition of a mark as opposed to learning the subject under study.

Finally, beforehand, it was expected that the students who use the tools based on controlled-error training in the different subjects would obtain better results, both because of their functionality as detectors of common errors, and because of their greater dedication to the subject, at the same time as it is frequent that the students who follow the subject regularly are the ones who participate most in all types of proposed activities, including the error-controlled training tool. In fact, according to the surveys of students who had the error-controlled testing questionnaire available to them, in all subjects, the majority of the people who used it were students who attended class regularly. Moreover, most of them believe that they obtained a higher mark than if they had not tested with these questionnaires since, having to detect errors, had helped them to reason more and fix better the concepts studied (Fig. 9.9). The way to minimize the impact of the almost exclusive use of the method by students who regularly follow the course is to increase student participation, making the activities containing error-controlled exercises compulsory or considering their completion as part of the continuous evaluation. Taking into account all these considerations, it should be noted that the proposed error identification methodology presents greater advantages and is of greater interest from the teaching point of view if it is used as a learning system than if it is used as an evaluation system.

Although the application of the method did not show a significant improvement in comparison with other groups of students who had not used the controlled-error training tool, the students' perception of the usefulness of this methodology was very positive. With the results obtained, it can be concluded that the methodology is also applicable in contexts of total presentiality, since the 2021/2022 academic year was the first one with a return to normality after the two years of pandemic suffered by COVID-19 and, in addition, the tool has been used much more by the students. Considering that its use is voluntary, this increase means that the students' perception is that the tool is useful in their learning process.

9.6 Conclusions

Error-controlled exercise training has proven to be a tool that improves student learning. In this experience, it has become clear that this type of methodology is well received by students, since they perceive that it improves their learning, as shown in the satisfaction surveys carried out. The improvement of marks and the distribution of the results obtained by the students confirm the positive impact of this training on the transfer of acquired skills.

It should be noted that, when new methodologies are applied, the students who attend lessons and actively follow the subject are the ones who use the methodology the most, especially at the beginning of its implementation. This fact must be

considered when evaluating the results. Nevertheless, it was found that the methodology reduces mark dispersion and tends to mark normal distribution, therefore, the methodology reduces differences among students and equalizes knowledge. On the other hand, it is necessary to highlight the good reception it has had among the students, who have stated that this type of exercise has helped them to settle knowledge, as shown by the satisfaction surveys carried out with the students after the implementation. This result, for future courses, is very positive, as the methodology was found to be a measure that motivates and encourages the completion of training prior to evaluation by all students. Measures like this, which increase the personal study of students, should be encouraged and implemented.

The methodology used and validated in this chapter, which focuses on considering the error in the source of learning, presents, as one of its main advantages, the development of the critical spirit of the student. The importance of this ability lies in its transferability since it is something that will be applied in all spheres of life. It is not just about learning mechanically the correct resolution of the mistakes they make, but about being able to find errors in content that are presented as correct, analyze them, evaluate them, and solve them.

Due to the good results obtained in the previous research, partially implemented during the Covid-19 pandemic, the methodology was reapplied in the post-pandemic period (academic year 2021/2022) to validate it. The same good results were obtained again, so it is intended to continue using it in the future. In addition, the methodology has an important advantage: your own feedback. Since the methodology is based on inserting controlled errors, the students themselves, by taking exams, allow lecturers to identify the most common errors to be inserted in future exercises. This is another reason why the methodology has had such positive results. As controlled errors are frequent errors, their detection by students leads to substantial and visible improvement in a short period of time.

Positive results obtained in the student satisfaction surveys make this methodology another tool at the service of students to reinforce learning and maintain it at optimal levels despite the lack of face-to-face activities in some phases of the course. Furthermore, the fact that, in many subjects, the response time of these exercises were short, makes it possible to streamline the exercises by increasing the motivation of the students to do them.

Lastly, it is worth highlighting the high transferability of the methodology to other subjects, not necessarily of a technical nature, although it is true that it requires the incorporation of minor adjustments in the types of questions depending on the subject. The detection of errors can be extrapolated to any subject in which critical thinking is required, therefore, it is expected to incorporate new subjects in the next courses. The good results obtained together with the versatility of the methodology make it a good tool to promote learning.

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Chapter 10
Programme for the Prevention of Musculoskeletal and Psychosocial Disorders in Professional Training

Marly Cordones García

Abstract The objective was to analyse whether the behavioural intention towards the promotion of a preventive culture in the organisation, regarding the postural and emotional habits of students to whom the MSD prevention programme was applied, differed from that of those not involved in the programme. The intervention consisted of creating a specific posture and emotional behaviour programme which would subsequently be applied using a series of continuous actions in seven professional training centres throughout Spain. It was applied to a sample of students and teachers from different educational cycles and grades over two consecutive years. The measuring instrument was an ad hoc questionnaire. This questionnaire set out various occupational scenarios and everyday situations likely to involve a postural and psychosocial risk. The results indicate that there is evidence that the application of the intervention programme modified the behavioural intention and the attitude of the majority of the sample. The necessary preventive culture includes adequate training during the initial phases of training for professionals, in which the acquiring of skills is aimed at employment, drawing attention to the fact that younger participants were more willing to learn.

Keywords Posture · Preventive culture · Professional training · Musculoskeletal and psychosocial disorders

10.1 Introduction

Back pain and discomfort are not just the result of poor postures adopted during work, they are also associated with various occupational factors such as the manual handling of loads, forced postures, repetitive movements or psychosocial risk factors. The high incidence and prevalence of sick leave due to musculoskeletal damage and disorders (MSDs) and the constant search by companies to reduce these risks, due

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_10

to the high cost they incur, as well as the "multi-causality" that accompanies them, means that companies are adopting measures to mitigate the effects of inadequate postural hygiene.

The damage caused by poor postural habits presents as back injuries and pain, which results, in all countries, in a high cost due to sick leave (due to occupational accidents and professional illnesses) and means that this is one of the main causes of sick leave and one of the main occupational health problems in Europe (Carrillo et al., 2003).

Technical Notes of Prevention (NTP) 745, 829 and 830 (National Institute of Occupational Safety and Health, 2006, 2009a, 2009b) focus on prevention, work by and for the health of persons, assuming that an excellent and successful company is based on people and their behaviour. The preventive culture must be proactive, in which the procedures are instruments to consolidate habits and manage skills. Cultural change requires unconventional strategies, where the emotional aspect plays a decisive role in the process. These skills, and their acquisition in an educational setting, can be used as the basis for the creation of a preventive culture, but through an educational intervention in which the student acquires the ability to learn significant lessons by themselves in different situations and new circumstances. Coll (1991) confirms that "the knowledge construction process does not depend solely on what students do; it requires a joint structuring of activity".

In the Education System, numerous interventions have been established at infant, primary and secondary levels (Aguado, 1995; Aguado et al., 2000; Baranda et al., 2006; López-Miñarro, 2000; López-Miñarro et al., 1998; Pujante, 2014; Rodríguez, 2006; Santonja et al., 2017), aimed at improving postural education in schools and providing research and materials useful for this objective, and others highlighting the importance of the factors internal and external to the individual, such as elements to predict their behaviour, including social behaviour learnt relating to postural hygiene (Kolb & Fry, 1975).

None of these interventions was aimed at professional training, which is the bridge between training and employment and key to providing awareness of the risks and dangers the student faces when entering the world of employment (Widanarko et al., 2015).

Intervention programmes implemented in the school environment have the following characteristics:

1. Short duration or one-off interventions, applied to infant, primary and secondary levels. As specified by Santonja et al. (Santonja et al., 2017), the majority of postural education programmes are interventions applied in a single session (Kovacs et al., 2011; Spence et al., 1984) up to interventions applied in one week (McAuley, 1990; Robertson & Lee, 1990; Sheldon, 1994), 2 weeks (Cardoso, 2009), 4 weeks (Vidal et al., 2010), 6 weeks (Cardon et al., 2000, 2001, 2001a; Dolphens et al., 2011; Park & Kim, 2011; Vidal et al., 2011), 8 weeks (Gómez-Conesa & Méndez, 2000), 11 weeks (Méndez & Gómez-Conesa, 2001) and 15 weeks (Cardon et al., 2001).

2. All the interventions take place during the physical education class or involve physiotherapists or doctors, and are analysed from a technical point of view.
3. There is no intervention programme to prevent postural and psychosocial risks at the Professional Training level as a programme to acquire an appropriate preventive culture so that the student acquires preventive awareness in the prevention of postural and psychosocial risks, which will improve health and well-being when adapting to employment.
4. In addition, the Occupational Training and Guidance module has never included a cross-sectional module in Training Cycles for Professional Training, an intervention in which the key lesson involves health skills, especially body and emotional movement as a preventive measure for occupational risks.

Article 23.3 of Royal Decree 1147/2001 of 29 July, which sets out the general regulations for professional training in the education system, indicates that the training established in the professional Occupational Training and Guidance module provides the skills to undertake professional responsibilities equivalent to those required by basic level activities for the prevention of professional risks, as set out in Royal Decree 39/1997 of 17 January approving the Regulation on prevention services. It also states that: "… 2. This module will include training in the prevention of occupational risks, regardless of their cross-sectional processing in other professional modules, according to that required by the professional profile". These skills form part of the performing of functions corresponding to the basic level in risk prevention (RD 39/1997) and include "Promoting safe behaviour and the correct use of work and protective equipment, and enhancing the interest and cooperation of workers in the preventive action".

Postural and emotional hygiene: healthy back follows the objective set out by the European Parliament in its *Europe Strategy 2020* (training professionals and improving their employability) and looks to reduce absenteeism from work and train workers in preventing occupational risks. Social changes have involved individual measures with the aim of improving quality of life and acquiring strategies and instruments that can be used to deal with these changes on a daily basis.

The objectives set for this programme were the following.

Designing a questionnaire to evaluate the behavioural intention and attitudes towards body and emotional behaviour in situations that typically involve greater risk.

Evaluating knowledge of postural hygiene: declarative and essential elements of the basic training aspects regarding postural hygiene.

Carrying out an experimental study to empirically record the influence of the intervention on the awareness of the Professional Training student and teacher with regard to ergonomic and psychosocial occupational risks and their adaptation to new situations.

The general objective was to analyse the impact of body and emotional behaviour on the behavioural intention and attitudes of the Professional Training student and teacher, and to educate about appropriate postural and emotional habits given the risks of the environment.

In today's dynamic and changing environment, we must look after our personal and occupational health. It goes without saying that the success of any health promotion programme must include clear behavioural theories and their change processes.

According to Prochaska and Bonacci (2003): "The better the factors that influence a desired behaviour and the social context in which it occurs are understood, the more chance there is that the intervention will have an impact on the desired behaviour".

To achieve awareness of the postural and psychosocial risks due to physical and mental load, giving rise to musculoskeletal disorders:

1. There is a need for adequate mechanisms and tools for the detection and identification of the risks to which people are exposed when exercising any profession.
2. Adopting preventive measures, such as postural and mental control and balance (Widanarko et al., 2015) can avoid personal, economic and social effects.
3. Including it in the teaching–learning process, from the training and acquisition of skills through and for the job, will make our students adopt new habits and provide internalised global and integral learning, helping them acquire a level of emotional maturity as people and be a stabiliser for growth (Aguado, 1995).

The concept of preventive culture must address the search for this balance and preventive training, not only in education but also in business. The Occupational Risk Prevention Law (LPRL) sets out that "the employer must guarantee that each employee receives sufficient and adequate theoretical and practical training in prevention…" and this is conducted through preventive policies from the Authorities, social agents and other organisations. Creating this culture lies in establishing routines rather than one-off interventions and training programmes. Combating risks in general, and specifically postural and psychosocial risks, cannot be limited to training and information about what might happen, but must be based on physical and mental awareness (Widanarko et al., 2015).

The professional training student acquires skills for the job and to carry out an occupation (Organic Law 5/2002) and, therefore, the structure of the training system and the different occupational groups mean that there is a wide range of forms of employment and work systems that affect the mind and the body.

In the educational sector, and in terms of levels of education in Professional Training in which the learning of skills is aimed at employment, skills must be acquired in an integrated and integral manner for adaptation to a dynamic, changing and complex work environment. Therefore, raising the student's awareness of adopting certain postural and emotional behaviour as a measure to prevent risks that cause MSDs is a way of creating prevention of the postural and psychosocial risks that cause these disorders, and must form part of the student's skill set. Among students in education cycles, as well as at all other educational levels, early intervention, with awareness programmes on how to prevent MSD, could play a very important role in modelling future medium to long-term behaviour.

10.2 Materials and Method

Using a pre-post test study, the responses of 394 students and teachers during the years 2018/2019–2019/2020 were analysed to study the intention regarding conduct, behaviour, attitudes and adaptation to change in the prevention of postural and psychosocial risks, to avoid MSDs and to promote a preventive culture within the organisation.

The measuring instrument was an ad hoc questionnaire which analysed the responses of a control group (15 women and 18 men) and an intervention group (181 women and 183 men) to different occupational scenarios and everyday situations likely to involve a postural risk and psychosocial risk, categorised by gender, occupational group, educational level (middle grade, higher grade or basic professional training) and age. Four blocks of risk factors were also established for subsequent comparisons: Category 1: position; Category 2: physical load; Category 3: postural load; Category 4: psychosocial load.

The sample comprised two groups (control and intervention) made up of students and teachers involved or not involved in the programme, respectively. The sample contains ages between 18 and 45, distributed between three occupational groups, according to the professional sector to which they belong (middle grade, higher grade, basic professional training and teacher) from seven national Professional Training centres.

The Occupation variable is categorised as follows:

- Group 1—Sound, lighting, electrical and automotive installations, and physical activities.
- Group 2—Administration, prosthetic audiology, administrative management, electromedicine and teaching.
- Group 3—Cooking, kitchen management and catering services, oral hygiene, pharmacy and parapharmacy.

There is also age-based categorisation (under 20 years of age, 20–25 years, 26–40 years and over 40 years of age).

These two groups were subject to three questionnaires:

- First questionnaire: conducted before the intervention and to which both groups were subject, made up of 23 questions using a Likert scale from 0 to 6 (where 0 is never and 6 is always), which revolve around awareness of behaviour posing a risk to the back in which postural hygiene knowledge is applied or not.
- Second questionnaire: conducted after the intervention and to which both groups were also subject, made up of the same 23 questions and another 25 questions using the same Likert scale from 0 to 6, which revolve around knowledge and attitudes of postural hygiene by respondents.
- Third questionnaire: conducted by the control group and by some of the students and teachers in the intervention group, which analysed the adaptation to change proposed by the intervention, creating an evaluation rubric with the skill to acquire and the specified level of performance: working in new situations.

In addition, said questionnaires asked about certain variables relating to the subjects (age, gender, occupation and location).

The programme was designed for application by the teacher of the Occupational Training and Guidance Module in Professional Training, and forms part of the Occupational Risk Prevention included in said module. The intervention consisted of the creation of a postural and emotional behaviour programme comprising four blocks of content:

- Block 1: Body recognition.
- Block 2: Body knowledge.
- Block 3: Postural control.
- Block 4: Emotional recognition, knowledge and control.

The intervention was applied over a total of two school years and by the participating centres simultaneously. The following actions were carried out:

- Presentation of the programme: 60-min classroom-based session aimed at the teacher with the aim of relying on the commitment and coordination of the players involved.
- Theoretical/practical training of the teacher: 120-min classroom-based session with the aim of providing the knowledge and tools to apply the programme to the reference groups. Session content: presentation of the blocks of content and activities in each block, sequencing and the process for completion of the questionnaires.
- Programme application sessions: one weekly 60-min session, which included the practice of activities from the four blocks in each session, and which were designed based on the physical and psychosocial demands of each professional profile and according to the categories established in the study: position, physical load, postural load and psychosocial load. They included physical and emotional behaviour, work using computer graphics and completion of consolidation sheets.
- Final intervention: one 120-min workshop which included the practice of the behaviour from all the blocks of content. This intervention took place remotely for some of the intervention groups due to the lockdown caused by the state of emergency.
- Feedback for the student: during the two courses of application to the programme, the teacher provided daily feedback. The main objective was for the students to be aware of the behaviour intervention programme to improve postural and emotional habits.
- Collective challenge: once per semester, a collective inter-centre challenge took place which consisted of the creation of choreography by the student, combining the programme's behaviour with a melody, demonstrating balance, coordination, postural control and teamwork.

The first and second questionnaires were customised and considered that the body is required to carry out physical and psychological work, not just in the work environment but also in everyday tasks.

The National Institute of Occupational Health and Safety (INSST), which is the specialist scientific-technical body of the General State Administration answerable to the Ministry of Labour and Social Economy, and the classification from the European Agency for Health and Safety at Work (EU-OSHA), rates the risk factors and risks, possible causes of musculoskeletal disorders, as ergonomic risks, environmental factors, workload and working with computers. It can be deduced that each one, individually and combined, can be the cause of musculoskeletal disorders. We must not forget that, when designing the workstation, consideration must be given to mental load and psychosocial factors, i.e. the requirements of the post and the individual's capacity for adaptation and ability to perform their profession.

On this basis, we pose the following situations as work scenarios which are susceptible to postural risks, and subject to awareness in the performance of the profession.

The following should be considered in terms of the behavioural intention:

1. Standing.
2. Sitting.
3. Lying down.
4. Poor positions when carrying out any activity involving physical movement.
5. Lifting weight.
6. Repetitive movements.
7. Lack of rest.
8. Lack of training and information on the risks.
9. Instability when carrying out any activity involving physical movement.
10. Posture maintained when exercising an activity.

The following were considered in terms of psychosocial risks and risk factors:

1. Conflicts with colleagues.
2. Workload.
3. Personal problems.

The following should be considered in terms of knowledge and attitudes:

1. Content (postural and psychosocial, ergonomic risks, etc.).
2. Social influences (colleagues and people in authority).
3. Personal (awareness of the risks to own health).

The third questionnaire analysed the ability to adapt to change with performance level: working in new situations in the following dimensions: Intermediate-Advanced-Outstanding (4-, 6-, 8-, 10).

All subjects were guaranteed data confidentiality.

The first questionnaire was conducted by the participants before the programme's first session. General information was extracted from this questionnaire (age, gender, occupation and location).

The second and third questionnaires were conducted once the programme's last session was complete.

The intervention programme was designed by experts in the subject area: a doctor, a body biomechanics expert, a psychologist, a physiotherapist and a graduate in physical and sports activities, who held 4 meetings on the design and development in each of the intervention sessions.

The study data was analysed once the two courses were complete, and was collected remotely due to the lockdown. An online database was created for this purpose, thus maintaining the confidentiality of the participants.

In order to interpret the data extracted from the first two questionnaires, the differences between the responses to the questionnaire before and after the intervention were analysed.

To analyse the reliability of the scale, we verified its internal consistency using Cronbach's alpha for all the items, as this measures the level of internal correlation between them. It must be greater than or equal to 0.7 to be considered satisfactory. In our case, the reliability analysis gave a Cronbach's alpha of 0.886.

To interpret the data extracted from the third questionnaire and review the adaptation to change of students in the intervention, the control group was compared with the intervention group.

10.3 Results

The added value of this intervention programme is the application of training throughout the study period, to make the entire educational community aware of the importance of overall health, creating active spaces, stimulating their interest in both postural hygiene and emotional hygiene to ensure students are capable of using dynamic strategies that awaken competence in skills development, promoting creativity and motivation and incorporating healthy postural and emotional habits that are clearly transposable to future employment. The results indicate that there is evidence that the application of the intervention programme has modified the behavioural intention and the attitude of the majority of the sample.

Firstly, the Postural Hygiene Questionnaire is analysed. It consists of 23 questions asked before and after the intervention, and used to study whether the intervention had an influence on responses. The Wilcoxon signed rank test was used to process the paired responses (at two different points in time for the same people).

Table 10.1 presents the medians of each item for the control group and the intervention group, before and after the intervention. It also shows the p-values corresponding to Wilcoxon's signed rank test performed, which compares the medians of each pair of items. A test's p-value quantifies the probability of error if the hypothesis being tested is rejected. In this test, the hypothesis tested is the equivalence of the medians. Therefore, p-values below 0.05 indicate that we can reject the equivalence of the medians or, in other words, that we can accept that the differences in the responses observed are statistically significant. P-values below 0.05 would indicate that the intervention is effective.

Table 10.1 Questionnaire on postural hygiene habits. Mean of responses

Control (n = 33)	Before	After	p-value	Intervention (n = 364)	Before	After	p-value
P1	0.39	0.58	0.109	P1	1.57	4.79	0.000[a]
P2	0.85	0.70	0.34	P2	1.54	4.96	0.000[a]
P3	0.79	0.70	0.527	P3	1.45	4.82	0.000[a]
P4	0.85	0.79	0.686	P4	1.17	4.66	0.000[a]
P5	0.91	0.76	0.477	P5	1.52	4.84	0.000[a]
P6	0.97	1.12	0.455	P6	1.48	4.83	0.000[a]
P7	0.70	0.79	0.58	P7	1.50	4.82	0.000[a]
P8	1.06	0.91	0.442	P8	1.37	4.87	0.000[a]
P9	1.27	0.76	0.005	P9	1.48	4.87	0.000[a]
P10	0.91	0.97	0.674	P10	1.63	4.89	0.000[a]
P11	1.00	1.42	0.046[a]	P11	1.46	4.80	0.000[a]
P12	0.88	0.91	0.796	P12	1.29	4.85	0.000[a]
P13	0.73	1.12	0.022	P13	1.26	4.68	0.000[a]
P14	0.88	0.94	0.648	P14	1.67	5.05	0.000[a]
P15	0.67	0.70	0.808	P15	1.44	4.85	0.000[a]
P16	1.00	0.42	0.005[a]	P16	1.45	4.63	0.000[a]
P17	1.09	0.94	0.289	P17	1.63	5.00	0.000[a]
P18	1.15	0.91	0.074	P18	1.39	4.72	0.000[a]
P19	0.91	1.15	0.087	P19	1.40	4.82	0.000[a]
P20	1.00	1.06	0.663	P20	1.46	4.85	0.000[a]
P21	0.97	1.15	0.305	P21	1.07	4.43	0.000[a]
P22	0.76	1.00	0.208	P22	1.41	4.87	0.000[a]
P23	0.61	1.12	0.005[a]	P23	1.28	4.60	0.000[a]

[a] Indicates that the p-value is significant (below 0.05)

The results are clear: while in the control group there are only significant differences in three questions (Q11, Q16 and Q23), the intervention group presents differences in all questions. In addition, the three questions that show differences in the control group show a less significant difference in the response than that produced in the intervention group. This means that there is evidence that the intervention has changed the responses given in the Postural Hygiene Questionnaire.

The following questionnaire relates to the student's knowledge of postural hygiene. The objective was to analyse whether differences occurred after the intervention between the control group and the intervention group. The Mann–Whitney U test was performed. This test is suitable for independent samples in the absence of normality, and uses the hypothesis to be tested as the null hypothesis, namely that the medians of the sample values are equal. It was observed that all differences between both groups are significant with p-values less than 0.01.

This means it is statistically proven that knowledge of postural hygiene differs between the control group and the intervention group, with this being greater in the intervention group. The differences in the variables within the intervention group were subsequently analysed based on the aforementioned categories. A comparison of the four categories of questions was made as follows:

1. Category 1: Position: questions relating to standing (1, 5 and 15), sitting (1, 3, 8 and 11) and lying down (5).
2. Category 2: Physical load: questions relating to lifting weight (6, 7, 10 and 13).
3. Category 3: Postural load: questions corresponding to poor postures when performing any activity involving physical movement (2, 9, 14 and 17), repetitive movements (12), instability in the performing of any activity involving physical movement (19) and posture maintained when performing any activity (20).
4. Category 4: Psychosocial load: it corresponds to questions 16, 18, 21, 22 and 23.

The sum of all the responses in a category is assigned to that category as the result. In this case, the before/after differences were analysed between control and intervention for each question and for the four categories. Therefore, an additional variable was created: the difference between the results before and the results after, and compared in the control and intervention groups using Student's t-test for the comparison of independent means: although the four variables associated with the categories are not normal, as the sample sizes are large enough, we can assume normality and use parametric comparisons (see Table 10.2).

Assuming that the intervention changed the responses, the variable difference between questionnaires was analysed before and after in the four categories by age group, occupational group and between men and women for the 364 subjects to have undergone the intervention. Student's t-test (gender) was used, as well as the ANOVA test for more than two groups (occupation and age) (see Tables 10.3 and 10.4).

When categorised by gender, the results were only significant in Category 4 (psychosocial load), where the intervention had a greater influence on men than women. However, significant differences were observed in all the occupational and age groups in the questionnaire's four categories. In terms of the knowledge questionnaire, differences by gender, age group and occupational group were analysed, with only the intervention group being reviewed, using Student's t-test in the case of two means and the ANOVA test in the case of more than two means. This analysis can be seen in the following Tables 10.5 and 10.6.

Table 10.2 Questionnaire on intentions and attitudes regarding postural hygiene, differences between the control/intervention groups before and after in the 4 categories

Category	Intervention group		
	Intervention before	Intervention after	p-value
C1	9.97	33.62	0.000[a]
C2	5.86	19.22	0.000[a]
C3	9.07	29.57	0.000[a]
C4	6.59	23.25	0.000[a]

[a] Indicates that the p-value is significant (below 0.05)

Table 10.3 Questionnaire on intentions and attitudes regarding postural hygiene, categorised by gender

Category	Gender		
	Differences men	Differences women	p-value
C1	24.59	22.70	0.097
C2	13.80	12.91	0.193
C3	21.13	19.86	0.221
C4	17.61	15.60	0.038[a]

[a] Indicates that the p-value is significant (below 0.05)

There are significant differences in 8 questions based on gender: between occupational groups in 11 questions and by age group in 13 questions. In general, it is observed that the average of the responses varies by an occupational group without a clear tendency, whereas by age group those aged over 40 tended, in the majority of questions, to respond with lower scores than the other groups.

Finally, the third questionnaire was used to review the adaptation to change of students in the intervention, in which the control group was compared with the intervention group. Said questionnaire was completed by the entire control group and by 112 students in the intervention group (see Table 10.7).

The results can be seen in the previous table. Student's t-test was used to compare the means of independent groups. No significant differences were observed between the results of both groups, with a level of significance of 0.05. We will now analyse the responses by gender, age group and occupational group of the subjects who completed the questionnaire for the intervention, applying Student's t-test for comparisons by gender and the ANOVA test for the other two groups (see Table 10.8 and 10.9).

There are gender-based differences in six questions. However, there are significant results in almost all the questions in the age group and occupational group variables. The lowest average values relate to group 2 and those aged over 40. In addition, analyses were performed based on occupational groups, age and gender for the categories of the first questionnaire before and after the intervention in case they are useful for future research.

10.4 Discussion and Conclusions

Based on the data extracted, we can conclude the following.

After application of the programme, there were differences by gender, with men being predisposed to the change in behaviour and attitude after application of the programme, particularly in category C1, standing, sitting and lying down, and in category C4, psychosocial factors, such as conflicts at work and excessive tasks.

The student who takes Professional Training in Middle Grade and Basic Professional Training is more receptive to the change in behaviour and to embracing preventive culture following these types of intervention programmes, compared to the Higher Grade and teacher groups.

Table 10.4 Questionnaire on intentions and attitudes regarding postural hygiene, categorised by active and age

	Occupational Group				Age Group				
Category	Differences Group 1	Differences Group 2	Differences Group 3	p-value	Differences < 20	Differences Group 20–25	Differences Group 25–40	Differences > 40	p-value
C1	27.93	19.24	25.81	0.000[a]	25.57	26.22	22.34	15.59	0.000[a]
C2	16.21	10.88	14.46	0.000[a]	14.19	14.62	12.84	9.49	0.000[a]
C3	25.25	16.73	22.06	0.000[a]	21.86	22.97	19.24	13.76	0.000[a]
C4	18.43	12.98	18.93	0.000[a]	17.56	19.01	15.00	11.57	0.000[a]

[a] Indicates that the p-value is significant (below 0.05)

Table 10.5 Questionnaire on knowledge regarding postural hygiene, categorised by gender

Questions	Gender		
	Men	Women	p-value
P1	5.31	5.34	0.721
P2	5.27	5.43	0.043[a]
P3	5.06	4.86	0.051
P4	5.09	5.22	0.168
P5	3.05	2.12	0.000[a]
P6	5.01	4.96	0.678
P7	5.39	5.42	0.766
P8	1.34	1.30	0.825
P9	5.05	5.38	0.000[a]
P10	4.97	5.23	0.029[a]
P11	4.91	4.82	0.588
P12	5.11	5.01	0.374
P13	4.70	4.61	0.626
P14	4.83	3.91	0.000[a]
P15	5.13	4.97	0.237
P16	5.03	4.54	0.007[a]
P17	4.86	4.22	0.002[a]
P18	4.97	4.84	0.311
P19	5.13	5.17	0.665
P20	5.27	5.26	0.903
P21	5.11	4.62	0.001[a]
P22	5.32	5.43	0.235
P23	5.36	5.46	0.261
P24	4.92	5.03	0.474
P25	4.97	4.76	0.117

[a] Indicates that the p-value is significant (below 0.05)

In some educational groups with occupations that involve risk factors due to workload, unstable positions and overexertion, the willingness to change behaviour is greater than in those with more sedentary positions, such as the Administration Cycle.

The change in behaviour is greater after application of the programme, particularly in the risk categories for standing, sitting and lying down positions; risks due to postural load such as poor positions in the exercise of any activity involving physical movement; repetitive movements; instability in the performing of any activity involving physical movement and posture maintained when performing any activity and psychosocial risks, such as workload, conflicts in the work environment or personal problems.

Table 10.6 Questionnaire on knowledge of postural hygiene, categorised by occupational and age group

Questions	Occupational group				Age group				
	Group 1	Group 2	Group 3	p-value	<20	20–25	26–40	>40	p-value
P1	5.36	5.27	5.35	0.623	5.35	5.28	5.34	5.32	0.937
P2	5.36	5.47	5.26	0.057	5.20	5.38	5.48	5.47	0.047[a]
P3	5.13	4.81	5.02	0.086	5.03	5.07	4.79	4.75	0.094
P4	5.28	5.18	5.10	0.487	5.04	5.21	5.14	5.31	0.265
P5	3.00	2.17	2.79	0.043[a]	3.02	3.26	1.71	1.15	0.000[a]
P6	4.98	4.76	5.14	0.013[a]	5.02	5.13	4.79	4.76	0.108
P7	5.47	5.38	5.41	0.814	5.36	5.44	5.47	5.37	0.819
P8	1.13	1.48	1.25	0.461	1.21	1.12	1.45	1.85	0.107
P9	5.04	5.22	5.25	0.368	5.11	5.17	5.26	5.49	0.055
P10	4.87	5.06	5.19	0.221	5.00	5.17	5.12	5.15	0.686
P11	5.04	4.76	4.90	0.496	4.94	5.05	4.24	4.93	0.005[a]
P12	5.00	4.83	5.25	0.002[a]	5.18	5.15	4.90	4.78	0.043[a]
P13	4.17	4.49	4.91	0.009[a]	4.74	4.85	4.19	4.54	0.085
P14	4.89	3.55	4.85	0.000[a]	4.85	4.92	4.10	2.49	0.000[a]
P15	4.91	4.81	5.26	0.006[a]	5.01	5.30	4.78	4.88	0.038[a]
P16	4.94	4.20	5.18	0.000[a]	5.12	5.18	4.28	3.76	0.000[a]
P17	4.32	3.90	5.07	0.000[a]	4.98	4.95	4.21	3.08	0.000[a]
P18	4.89	4.67	5.09	0.012[a]	5.09	5.11	4.71	4.31	0.000[a]
P19	4.87	5.04	5.30	0.008[a]	5.13	5.23	5.17	4.98	0.471
P20	5.28	5.10	5.38	0.067	5.47	5.33	5.10	4.86	0.002[a]
P21	4.79	4.45	5.20	0.000[a]	5.19	5.03	4.97	3.76	0.000[a]
P22	5.11	5.39	5.43	0.093	5.35	5.35	5.38	5.46	0.889
P23	5.26	5.45	5.42	0.371	5.33	5.37	5.53	5.54	0.232[a]
P24	4.81	4.82	5.13	0.097	5.07	5.01	4.79	4.88	0.585
P25	4.77	4.67	5.03	0.034[a]	4.91	5.15	4.81	4.25	0.000[a]

[a] Indicates that the p-value is significant (below 0.05)

The age group of the under-20s and the group of those aged 20–25 determined a greater influence on the change in their behaviour through the programme, as the over-40s and those in more sedentary occupations are more reticent to this change.

Finally, we can underline the less willingness to adapt to the change in behaviour shown by those aged over 40 and those in more sedentary occupational groups, highlighting that men adapt better to new situations when they have an external motivator to remain in the novelty, while women are able to incorporate resources and strategies to deal with novel situations.

Table 10.7 Questionnaire on adaptation to the change

Questions	Control	Questions	Control
P1	3.24	3.18	0.622
P2	3.39	3.24	0.221
P3	3.39	3.28	0.391
P4	3.39	3.30	0.473
P5	3.33	3.32	0.911
P6	3.39	3.29	0.452
P7	3.30	3.27	0.830
P8	3.33	3.30	0.798
P9	3.39	3.27	0.352
P10	3.36	3.30	0.628
P11	3.42	3.29	0.330
P12	3.42	3.29	0.338
P13	3.42	3.31	0.402

Table 10.8 Questionnaire on adaptation to the change, categorised by gender and occupation

Questions	Gender		
	Men	Women	p-value
P1	3.32	3.11	0.103
P2	3.39	3.16	0.067
P3	3.47	3.19	0.029[a]
P4	3.39	3.28	0.018[a]
P5	3.50	3.20	0.014[a]
P6	3.53	3.21	0.019[a]
P7	3.50	3.19	0.024[a]
P8	3.47	3.17	0.040[a]
P9	3.47	3.21	0.167
P10	3.37	3.27	0.436
P11	3.32	3.28	0.796
P12	3.39	3.24	0.271
P13	3.42	3.25	0.236

[a] Indicates that the p-value is significant (below 0.05)

After the literature search carried out to design the programme, we found many postural hygiene programmes at other educational levels, but none applied to the Professional Training level. This leads us to believe that there is still a long way to go before real awareness of prevention for employment and effective learning methods is created. The study carried out indicates that it is possible, with a Professional Training programme, to encourage the necessary preventive culture in Spain, carrying out continuous actions over time that promote change and creating awareness in

Table 10.9 Questionnaire on adaptation to the change, categorised by occupation and age

Questions	Occupational group				Age group				
	Group 1	Group 2	Group 3	p-value	<20	20–25	26–40	>40	p-value
P1	3.39	3.08	3.33	0.089	3.09	3.48	3.23	3.02	0.044[a]
P2	3.44	3.12	3.48	0.027[a]	3.27	3.48	3.27	3.07	0.104
P3	3.50	3.14	3.62	0.003[a]	3.45	3.48	3.31	3.07	0.047[a]
P4	3.44	3.18	3.62	0.010[a]	3.41	3.52	3.35	3.10	0.047[a]
P5	3.44	3.22	3.57	0.054	3.45	3.52	3.35	3.12	0.060
P6	3.39	3.18	3.62	0.023[a]	3.41	3.61	3.38	3.00	0.002[a]
P7	3.22	3.16	3.71	0.003[a]	3.36	3.57	3.42	2.98	0.002[a]
P8	3.17	3.22	3.71	0.004[a]	3.41	3.57	3.35	3.07	0.016[a]
P9	3.11	3.19	3.71	0.002[a]	3.32	3.52	3.38	3.05	0.026[a]
P10	3.11	3.22	3.76	0.001[a]	3.36	3.48	3.35	3.14	0.215
P11	3.11	3.19	3.81	0.000[a]	3.36	3.57	3.35	3.07	0.038[a]
P12	3.11	3.19	3.81	0.001[a]	3.41	3.65	3.31	3.02	0.004[a]
P13	3.17	3.20	3.81	0.001[a]	3.45	3.65	3.31	3.05	0.006[a]

[a] Indicates that the p-value is significant (below 0.05)

future professionals. It is shown that to achieve said results, adequate training is required during the initial phases of training for professionals, as the fact that younger participants are more willing to learn is striking.

Acknowledgements I would like to thank all participating students and teachers from the schools, particularly for their invaluable involvement, willingness and care with which they applied the actions in the programme during the difficult, delicate and sensitive times we have experienced during the pandemic.

• IES Profesor Tierno Galván. Alcalá de Guadaíra. Seville. Coordinator Sabina Gata Coronilla (OTG teacher). Control group.

• IES Politécnico Jesús Marín. Coordinator Esther Baeza Botía (OTG teacher). Intervention Group.

• IES Santiago Grisolía. Cuenca. Coordinator Nuria Contreras Mora (OTG teacher). Intervention Group.

• IES Francisco Tomás y Valiente. Madrid. Coordinators Blanca Merino Ojeda and Jesús Fernández de Vera. Intervention Group.

• CIPFP CHESTE. Cheste. Valencia. Coordinator M. Carmen Bayarri Cañadas. Intervention Group.

• CPIFP AYNADAMAR. Granada. Coordinator Marisa Ruiz Santiago. Intervention Group.

• IES Miguel de Cervantes. Murcia. Coordinator M. Carmen Caro López. Intervention Group.

• IES Cap de L´aljub. Santa Pola. Alicante. Marly Cordones García and Norma Cruzado Roque. Intervention Group.

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Chapter 11
Teaching Physics to First-Year University Students with the Flipped Classroom

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Abstract In this chapter, we present a teaching–learning process of the *Physics I* module with first-year university students based on the flipped classroom. The experience was conducted within the unit of the kinematics of the rigid solid in the 2021–22 academic term. We compare the students' performance with that obtained using traditional face-to-face master classes (2019–20), and with *fully on-line flipped* teaching during the COVID-19 pandemic (2020–21). The assessment using the flipped classroom in normal circumstances seems to be comparable with that of traditional teaching, but it seems to have been more limited within the unfavorable (fully on-line) pandemic context. Still, its ability to facilitate engaging attitudes toward learning and the positive students' perception encourage us to continue including these active methodologies that will surely have a deeper impact in the near future.

Keywords Flipped classroom · Active methodologies · Rigid solid · Physics

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_11

11.1 Introduction

Over the last years, the implementation of active-learning methodologies has been extended all over the different educational levels, ranging from primary school to university. The reason is simple: they facilitate the creation of processes and the assessment. Furthermore, according to Bloom's taxonomy, they develop higher-order cognitive skills, such as creating, evaluating, or analyzing, which assure a deeper and more significant learning (Morton & Colbert-Getz, 2016). Moreover, these methodologies place the students at the center of their own learning processes by making them the true protagonists of discoveries, rather than just passive-information receivers who learn by heart (Konopka et al., 2015). In other words, active methodologies are strategies focused on the effective participation of the students in their own learning processes in a flexible way, which simultaneously allows different relationships between facts and objects, this eventually leading to higher degrees of satisfaction and enrichment both for teachers and students (Calderon & Passos, 2020; Crisol-Moya et al., 2020).

The unexpected advent of the COVID-19 pandemic forced the educational system to abruptly adapt to an on-line teaching scenario, which was a formidable challenge for both instructors and students worldwide giving and receiving lessons from their own homes. This new reality required a sudden adjustment to new ways of teaching, where novel active activities were certainly boosted. In many cases, however, this change to the new environment was performed without adequate resources, training, or previous experience which could have a difficult solution due to the lockdown caused by the health crisis. Furthermore, sometimes students prefer traditional teaching, rather than other innovative methodologies, simply because they are more used to it. For all these reasons, among others, innovative methodologies have sometimes led to worse results in the students' performance, despite being expected to facilitate a more interactive atmosphere among students (Dhawan, 2020). In short, the improvement of traditional teaching and the implementation of new methodologies that are attractive to the students always require a great effort and the sincere commitment of both students and teachers (Fidalgo-Blanco et al., 2019).

The flipped classroom (Akçayir & Akçayir, 2018) is a remarkable example of a widely used active methodology. It was created by Jonathan Bergmann and Aaron Sams while teaching at the Woodland-Park High School (Colorado, USA). At that time, they observed high rates of absenteeism due to the long distances between the homes of some of their students and the high school, and then they decided to reduce them by incorporating a novel methodology.

The flipped classroom consists in performing the activities that are traditionally conducted in the classroom outside of it (especially through video lessons) and using face-to-face sessions to clarify doubts and solve practical exercises. As they report in their seminal books (Bergmann & Sams, 2012, 2014), this inversion of traditional teaching improves students' engagement. In fact, several studies have demonstrated the effectiveness of the flipped classroom to increase the engagement and motivation of the students during the teaching–learning process (Campillo-Ferrer & Miralles-Martínez, 2021; Latorre-Cosculluela et al., 2021; Marina & Ridlo, 2021).

Inverted teaching has, moreover, the following advantages (Fidalgo-Blanco et al., 2017; Tang et al., 2020):

- It enables asynchronous teaching. The videos usually provided can be visualized by the student anywhere at any time, as many times as necessary. This gives students temporal and spatial flexibility and improves their autonomy.
- The student is an active agent, whose commitment and attitude induce a deeper and more significant learning.
- The classroom time is much more effectively used. Instructors act as mediators supporting and guiding the students.
- It can facilitate on-line teaching by supporting individual development while using digital tools, which still can guarantee social distancing and ensure teachers and students remain in touch (Izaguirre-Olaizola & Morandeira-Arca, 2020).

Here, we report on the teaching–learning experience of the use of the flipped classroom in the 2021–22 academic term. This methodology was implemented in our case during the COVID-19 pandemic (2020–21 academic term) to teach first-year university students one of the units of *Physics I* module of the Degree in Agroenvironmental Engineering of the Universidad Politécnica de Madrid.

The outline of this book chapter is as follows. After this introduction, we next describe the case of study within which the experience of applying the flipped-classroom model has been conducted in Sect. 11.2. Then, the particularities of the experiment are briefly described in Sect. 11.3. Section 11.4 is subsequently devoted to the results of our work including comparisons with the records of the two previous academic terms (2019–20 and 2020–21). Finally, we conclude by presenting the final remarks of our work in Sect. 11.5.

11.2 Case of Study

The flipped classroom has been implemented in the teaching–learning process of the unit on the kinematics of the rigid solid of the *Physics I* module. In this module, first-year students of the Degree in Agroenvironmental Engineering of the Universidad Politécnica de Madrid are taught the essential principles of Physics.

The *Physics I* module is divided into the following six units:

1. Vector calculus.
2. Kinematics of the point.
3. Kinematics of the rigid solid (KRS).
4. Relative motion.
5. Statics (equilibrium, center of mass, and inertia moments).
6. System dynamics.

The flipped classroom was implemented during the academic term 2020–21 in order to facilitate on-line teaching, as the COVID-19 pandemic situation disabled traditional on-site teaching (except for the laboratory practices, which could take

place in-person in our university), in an attempt to encourage students' motivation. Though in the academic term 2021–22 on-site teaching has been reestablished, we have continued the teaching of KRS using the flipped classroom due to the previously mentioned advantages (see Sect. 11.1) with the aim of improving the way in which the methodology was applied. This fact enables, on the one hand, the comparison of the results of our students over the academic terms 2021–22 versus 2019–20 (when the KRS unit was taught using traditional master classes) in order to unravel the impact of the flipped classroom on the teaching–learning process. On the other hand, the comparison of the students' performance over the 2021–22 versus 2020–21 academic terms allows unveiling the influence of on-line teaching (and the situation itself) during the pandemic.

In the current 2021–22 academic term, the number of students in the *Physics I* module was 88, 68 of them (77% of the total) being first-time enrolled students. 68 students participated, at least once, in the flipped-classroom experience. During the previous academic term (2020–21), the *Physics I* module solely had 46 students, out of whom 38 were first-time enrolled. In that case, 25 of the students took part in the flipped-classroom experience (54% of the total). Finally, the *Physics I* module had 37 students in the 2019–20 academic term, when the unit on KRS was traditionally taught via master classes (on-site).

Let us conclude this section by remarking that all the students had suitable devices to visualize the videos and perform the activities. In the case of the 2020–21 academic term, one of the students did not have a laptop at the beginning of the teaching–learning process. Thus, he was given one so he could properly follow the virtual lessons (and perform all the activities associated with the flipped classroom).

11.3 The Flipped Classroom for Physics Teaching

As mentioned above, the flipped classroom has been implemented in the teaching–learning process of KRS. For this purpose, ten short videos were created, where brief explanations on this topic were included. Table 11.1 lists the main characteristics of the videos. As can be seen, all the videos are shorter than 5 min, so they could be quickly visualized (recall that long videos are usually counterproductive due to the lack of attention being a recommended duration between 2 and 6 min) (Guo et al., 2014; Thomson et al., 2014). The access to the videos was enabled through the Moodle platform to which all students have access as students of the Universidad Politécnica de Madrid. The students had two weeks to watch the videos as many times as necessary and answer the questionnaires related to them. At the same time, the units on relative motion and point dynamics in the face-to-face (on-site) classes were taught.

The first video (V_0) was devoted to briefly explain the flipped-classroom model, so it has not associated with any activity or questionnaire. The remaining videos were dedicated to the different concepts related to KRS, as indicated in Table 11.1. During this time, the instructor was always accessible to answer their questions and solve their doubts.

Table 11.1 Characteristics of the V_0-V_9 videos used in the teaching–learning process of the unit of the kinematics of the rigid solid using the flipped classroom, and relation to the partial exam. t_d is the duration, t_c the limit time to answer the corresponding questionnaires, and Q_i the question of the exam exercise more related to the video

V_i	t_d	t_c	Content	Q_i
V_0	$2' 4''$	–	*(Brief explanation of the flipped classroom)*	–
V_1	$3' 5''$	$30'$	What is it?	–
V_2	$4' 9''$	$30'$	How can it move? (translation and rotation)	Q_1
V_3	$3' 17''$	$20'$	How are translations composed?	
V_4	$3' 20''$	$30'$	How are rotations composed?	
V_5	$4' 6''$	$30'$	How is pair of rotations composed?	
V_6	$1' 19''$	–	How are translations and rotations composed?	
V_7	$3' 31''$	–	How is the velocity of a point related to the velocity of another one?	Q_2
V_8	$4' 11''$	$60'$	What are the invariants?	Q_3 (& Q_6)
V_9	$4' 14''$	–	How is the instantaneous axis of rotation calculated?	Q_4 and Q_5

The flipped-classroom assessment was conducted through nine short activities (eight of them questionnaires), which had to be filled out in Moodle after visualization of each of the videos. As reported in Table 11.1, six of these questionnaires were time-limited, while the remaining four were not. As will be seen in the results section (and in Table 11.1), each video has an associated exam question related to the content of the video.

A Science-Technology-Society perspective was included in the exercises associated with the V_7 video. In these activities, the students had to draw, at a certain instant of time, the velocities (of translation and rotation) of two persons doing skateboard and parkour (in two additional videos also available on the Moodle platform). In this way, the students could see the daily application of the concepts covered in the class, something that was expected to increase their motivation and engagement with the subject.

In order to ensure the correct understanding of the concepts explained in the videos, after the two-weeks period of the flipped classroom, the most complicated concepts were more extensively explained in an one-hour face-to-face (on-site) session. Some examples of these difficult issues are *What is a pair of rotations* or *What is the instantaneous axis of rotation.*

Lastly, two 1 h 15 min sessions were dedicated to solve practical exercises in the classroom. These exercises were very similar to those that later appeared in the partial exam, which combined several of the concepts explained in the videos. Besides, in the last in-person session, the 43 students (79% of those who participated at a certain point in the flipped-classroom experience) were asked to solve an exercise that was taken into account in their continuous assessment. That day, a satisfaction survey formed by 15 questions was given to the students in order to find out their opinions on the methodology, the devoted time, the materials, and the possible improvements of the experience.

After the sessions with the teacher, the students had one more week to repeat those questionnaires in which they had obtained lower marks in order to correct their mistakes or do the questionnaires for the first time. This assured that the final assessment was carried out once all students had had the opportunity to resolve their doubts and questions. Moreover, the most motivated students had the opportunity to obtain extra points by solving two optional exercises (such as those discussed in the last two sessions with the instructor).

Above all, throughout the whole experience (which lasted in total 3 + 1 weeks), the teacher was always available to answer all the questions from the students.

11.4 Results

In this section, we study the performance of our students in the KRS unit of *Physics I*, which was taught using the flipped classroom in the 2021–2022 academic term. The corresponding data analysis has been carried out by introducing the matrices with the students' marks in a MS Excel sheet. For a proper comparison of the individual exercises, all marks have been normalized to 10 points.

This section is divided into two parts. For one thing, we discuss in Sect. 10.4.1 the results of the flipped-classroom questionnaires and compare them with those obtained in the partial exam (celebrated in October 2021). For another thing, and in order to provide a better understanding of these results, we revisit the performance in the previous years within other contexts in Sect. 10.4.2 (traditional teaching in the case of the 2019–20 academic term, and on-line *flipped* in the 2020–21 academic term due to the COVID-19 pandemic).

11.4.1 Teaching with the Flipped Classroom Over the Academic Term 2021–2022

Table 11.2 summarizes the performance and participation in the brief questionnaires that were used for the assessment of the flipped classroom. Although the students knew that these questionnaires were taken into account for the continuous assessment, only 29 students of the 88 enrolled (32%) in the module answered all of them. On average, 60% of the students answered the questionnaires, with an average mark of 5.8 out of 10 points. The average standard deviation equals 2.7, being for most of the videos larger than 2.2. This considerable value could be explained by the disparity in the students' backgrounds. Thus, the following conclusions of our work must be considered with some care. Still, after analyzing Table 11.1, we can conclude that the duration of the videos and the time spent by the students answering the questionnaires seem to have no influence on the final marks obtained by the students.

Let us discuss next the results obtained in each of the questionnaires. Videos V_1 and V_2 involved the easiest and most elementary concepts on KRS and, therefore,

Table 11.2 Participation and performance in the questionnaires associated with the $V_1 - V_9$ videos of the flipped classroom. μ is the average mark, σ the standard deviation, N the number of students, % the participation percentage, and $\overline{x}$ the weighted average

V_i	μ	σ	N	%
V_1	8.2	2.2	61	69
V_2	8.3	1.5	59	67
V_3	8.6	2.7	58	66
V_4	2.2	3.5	56	64
V_5	5.8	3.8	53	60
V_6	4.6	2.9	37	42
V_7	4.8	3.1	56	64
V_8	5.0	2.4	51	58
V_9	3.9	2.3	48	55
$\overline{x}$	5.8	2.7	53	60

most of the students (over 67% of them) answered the corresponding questionnaires with superb marks (over 8.2 out of 10 points). This is also the case of the V_3 video, which has been also extensively answered (by 66% of the total students) with excellent performance (8.6 out of 10 points). This video is related to the composition of translations, which is a rather simple task. However, the results obtained in the following videos are worse. In fact, among all the questionnaires, the worst results are obtained for the V_4 video, which has an average mark of 2.2. This video is associated with the composition of rotations, something that requires, in general, a high abstraction degree and therefore this result was expected. Quite unexpectedly, the results are much better for the questionnaire associated with the V_5 video, which studies the velocity rendered by a pair of rotations. This video had an average mark of 5.8, but still a considerable standard deviation of 3.8. The V_6 video was related to the composition of translations and rotations. The corresponding questionnaire has the lowest participation (it was answered by solely 42% of the students), with an average mark of 4.6 points. In the case of the V_7 video, the students were asked to perform a task on the same topic (the composition of translations and rotations), but with a Science-Technology-Society dimension, as previously discussed. This question has noticeable participation (the corresponding questionnaire is fulfilled by 64% of the students), probably, due to its connection to students' interests, but with a modest average mark of 4.8 points. A similar average mark (5.0 points) is obtained in the questionnaire associated with the V_8 video, but it has slightly lower participation (58%). This video presents the invariants of the rigid solid. Finally, the results for the questionnaire of the V_9 video are the second worst ones (3.9 points with modest participation of 55% of the students). This fact is reasonable since it is related to the computation of the instantaneous axis of rotation, which is in general regarded as a difficult task by most of the students (recall that this task required an on-site session for a more extensive explanation).

Table 11.3 Results obtained in the optional on-line exercises 1 and 2, and in the on-site exercise (3) associated with the units of the kinematics of the solid rigid. μ is the average mark, σ the standard deviation, N the number of participants, and % the participation percentage

V_i	μ	σ	N	%
V_1	5.3	3.6	16	18
V_2	5.6	3.4	13	15
V_3	7.4	2.7	42	48

As reported in Table 11.3, the optional on-line exercises had a rather modest participation. Actually, the first one was solved by only 16 students (18% of the total) with an average mark of 5.3 points, while the second exercise was carried out by 13 students (15%) obtaining 5.6 points on average. Contrarily, the on-site exercise solved in the last face-to-face session had much higher participation and performance: it was done by 42 students with an average mark of 7.4 points.

In general, those students who did well in the flipped-classroom questionnaires had also a good performance in the optional exercises, although the obtained average value is not too high. Furthermore, the on-site exercise was fulfilled by 40 out of the 67 flipped-classroom students. Of them, 32 got a mark of more than 5 points, 24 of whom (75% of them) are also marked with more than 5 points in the flipped-classroom questionnaires. Its average value is somewhat unexpected, since, as we will see below, it is considerably larger than the result obtained in the KRS exercise in the exam.

To sum up, these results, albeit subtly, seem to show an adequate impact of the flipped classroom.

Impact of the flipped classroom on the examination marks

Let us compare here the performance of our students in the flipped-classroom activities with that yielded in the partial exam, which was solved by 67 students (77% of the total). Among them, 59 had participated in the flipped classroom, and 15 were repeaters (12 of whom did also take part at a certain point in the flipped-classroom experience).

To begin with, we present in Fig. 11.1 the mark in the different questions of the KRS exercise of the partial exam as a function of the corresponding questionnaires related to the same aspects of KRS using the relations established in Table 11.1. Recall that the contents of the questionnaires were not exactly the same ones as those included in the partial exam; in general, the examination questions combined several of the concepts and were, as a consequence, more difficult. Note also that some of the marks for the flipped-classroom activities have negative values. The reason for this is that we have assigned -0.5 points to those students who did not answer some of the questionnaires, and -1.0 points to the students that did not answer any of them. We have assumed that unanswered questionnaires correspond to non-visualized videos. In this way, we can distinguish the totally wrongly filled-out questions (marked with 0 points) from those unanswered.

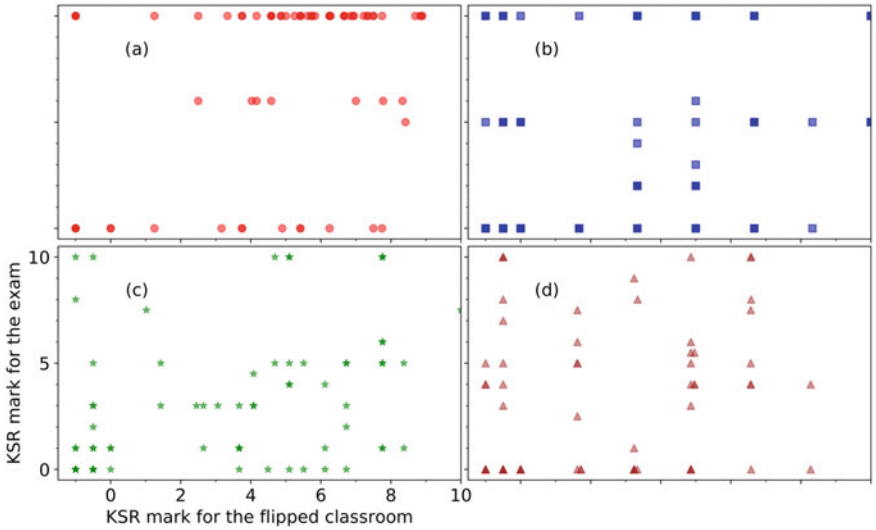

Fig. 11.1 Mark for the questions Q_1 (**a**), Q_2 (**b**), $Q_3 + Q_6$ (**c**), and $Q_4 + Q_5$ (**d**) of the exercise associated with the kinematics of the rigid solid for the partial exam of the 2021–2022 academic term as a function of the marks obtained in the flipped-classroom questionnaires related to the videos $V_2 - V_6$ (a), V_7 (**b**), V_8 (**c**), and V_9 (**d**), respectively (see Table 11.1). Negative points in the flipped-classroom questionnaires correspond to students who have fulfilled none (-1.0) or only some of them (-0.5) (see main text)

The data have a tremendous dispersion (the statistical dispersion exceeds 2.3 points for the flipped-classroom data and 3.2 for the exam questions), something that can be explained because of the different academic backgrounds of the students. Still, as shown in Table 11.4, the average mark for the computation of the origin velocity (Q_1) is substantially higher than that for the corresponding flipped-classroom questionnaires (associated with V_{2-6} videos), as it was 7.2 versus 5.1. There are almost no differences in the case of the computation of the velocity of one point as a function of the velocity of another one (Q_2 and V_7), where the average marks were ~ 4.8. The marks are lower in those tasks associated with the invariants (Q_3, Q_6, and V_8), where the flipped-classroom average mark was much higher than that of the exam (4.8 vs 3.4 points). The marks are also slightly worse for the questions associated with the instantaneous axis of rotation (Q_4, Q_5, and V_9), as it is reduced from 3.9 to 3.1 points. To summarize, despite the high degree of participation, it is not possible to ensure that the performance in the exam is improved with the flipped classroom.

Figure 11.2 shows the global marks in the KRS exercise of the exam as a function of the marks obtained in the different answers, which have been grouped into different concepts. As can be seen, the dispersion in the data is again quite high, as it happened in Fig. 11.1. Still, a clear tendency is visible: in general, those students who perform better in the different questions do also get better qualifications in the exercise, a fact shown by the positive tendency of the linear regressions added to the different panels, which must be taken with some care due to the small values of the regression

Table 11.4 Mark for the questions Q_i of the exam exercise on the kinematics of the rigid solid grouped as reported in Table 11.1 for the 2021–2022 academic term. In parenthesis, results for the flipped-classroom activities related to the corresponding videos. $\overline{x}$ gives the average mark. All results have been normalized to 10 points

	μ	σ
Q_1 ($V_{2\text{–}6}$)	7.2 (5.1)	4.2 (2.5)
Q_2 (V_7)	4.8 (4.7)	4.2 (3.2)
$Q_3 + Q_6$ (V_8)	3.4 (4.8)	3.2 (2.6)
$Q_4 + Q_5$ (V_9)	3.1 (3.9)	3.5 (2.3)
$\overline{x}$	4.2 (4.6)	2.8 (2.6)

parameters (in the best case $R^2 = 0.65$). Notice that the results shown in Fig. 11.2a and, to a certain point, in Fig. 11.2b, are strongly grouped in some particular x-values. The reason for this fact is that the assessment in questions Q_1 (related to the velocity of the origin) and Q_2 (on the calculation of the velocity of a point with respect to that of the origin) has been performed using a rubric that only considered these values. More marks are possible in the case of Fig. 11.2c, d, as in that case the shown data corresponds to the sum of the assessment of questions Q_3 and Q_6, on the one hand, and of questions Q_4 and Q_5, on the other hand.

In order to unveil the contribution of each question to the global mark of the KRS exercise, Pearson's correlation coefficient has been computed. As shown in Table 11.5, Pearson's coefficient for all the questions is positive and, except the Q_4, its

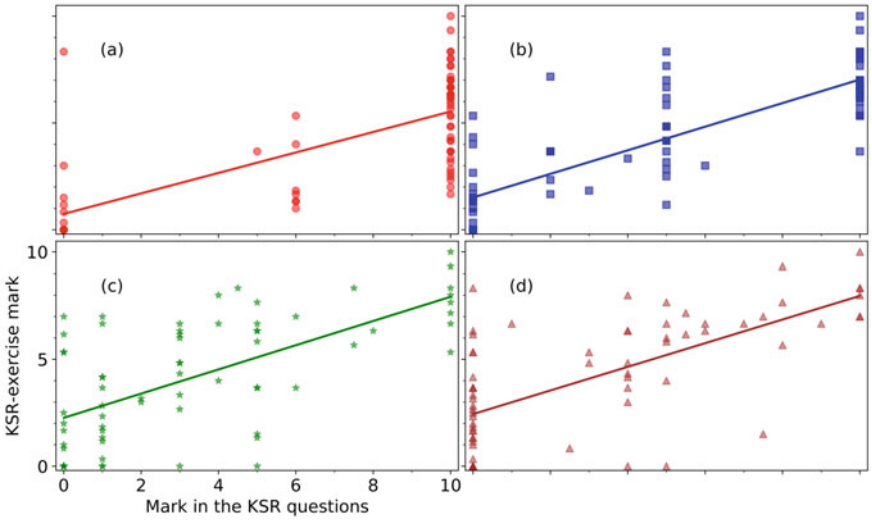

Fig. 11.2 Average mark for the KRS exercise in the partial exam as a function of the mark obtained in its questions Q_1 (**a**), Q_2 (**b**), $Q_3 + Q_6$ (**c**), and $Q_4 + Q_5$ (**d**). The continuous lines show the corresponding linear regressions, which have squared parameters equal to $R^2 = 0.50$, 0.65, 0.41, and 0.65, respectively

Table 11.5 Pearson's correlation coefficient (P) between the mark in the questions Q_1-Q_6 and the global mark of the exercise of the kinematics of the rigid solid in the exam

Q_i	P
Q_1	0.810
Q_2	0.856
Q_3	0.846
Q_4	0.553
Q_5	0.746
Q_6	0.790

value is very similar, lying within the range (0.74, 0.86), which demonstrates the similar importance of each question for the global qualification of the exercise. The lower value in the Q_4 question could be related to its content, which is the calculation of the instantaneous axis of rotation, being one of the most complex concepts on KRS.

Once the influence of the individual questions of the KRS exercise has been analyzed, we compare the performance of those students who took part in the flipped-classroom experience with those who did not. The average mark in the partial exam by the 59 *flipped-classroom* students (12 of them repeaters) was 3.2, while the eight students (three of them repeaters) who took the exam but did not follow the flipped classroom got, on average, 1.4 out of 10 points. This remarkable difference is, nevertheless, not significant, as concluded after performing the statistical tests (F- and T-tests), since the number of participants in the experience is quite higher than those who did not participate. The impact of the flipped classroom is clearly unraveled when only examining the 13 students that pass the exam, i. e., those marked with at least 5 points. 11 of these students (85% of them) were similarly marked with more than 5 points in the flipped-classroom activities and got good marks in the KRS-exam exercise. The two remaining students who passed the exam were repeaters (there is also another one who filled out the flipped-classroom activities). All of them get 5 or more points in the KRS-exam exercise. Taking into account that only 32 students (out of 88) answered all the questionnaires, this percentage suggests that, although we cannot assess the effectiveness of the flipped classroom, the model helps the student who uses it.

We conclude the discussion on the qualifications of the 2021–22 partial exam by comparing the assessment for the different exercises in the partial exam. For this purpose, we show in Fig. 11.3 the examination marks as a function of the marks of the four exercises that constituted the first part of the course, namely two on point kinematics, one on KRS, and one on relative motion (see Sect. 11.2). Still, a clear tendency toward higher global marks with the individual marks is certainly visible. Let us note that, among all exercises, KRS is the one with the largest average qualification (4.2 points vs 3.3 points in the exercise with the second highest mark). Nonetheless, this difference has no statistical significance due to the large standard deviation. Still, we have observed that the KRS exercise is the most strongly correlated exercise with the global exam mark, as inferred by its squared regression parameter ($R^2 = 0.77$). Again, we cannot relate these better results directly with the use of the flipped-classroom methodology, but we can see a slight influence.

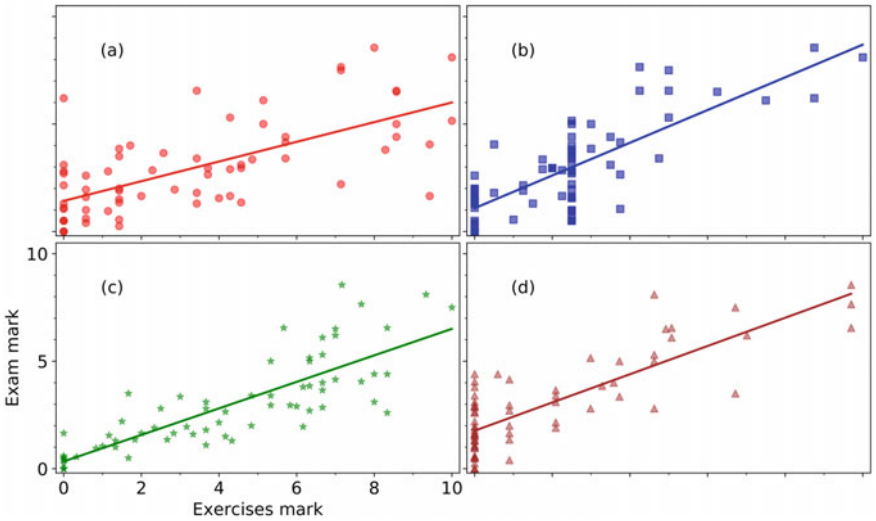

Fig. 11.3 Average mark for the partial exam as a function of the mark obtained in each of its exercises: kinematics of the point 1 (**a**) and 2 (**b**), kinematics of the rigid solid (**c**), and relative motion (**d**). The continuous lines show the corresponding linear regressions, which have squared regression parameters equal to $R^2 = 0.56$, 0.71, 0.77, and 0.67, respectively

Satisfaction survey

Let us conclude the discussion on the flipped-classroom experience over the 2021–22 academic term by presenting here the main findings of the satisfaction survey, which was answered by 49 students (72% of the participants in the flipped-classroom experience and 56% of the total number of enrolled students).

In general, most of the students found the experience positive and interesting (average mark 7.1 out of 10 points). Moreover, they think that the lessons with the teacher after the visualization of the videos are more useful (7.5 points). However, 65% of the students prefer the traditional teaching, arguing in most cases that it is more personal and allows them to solve their doubts at the time of the explanation. On average, the students who answered the survey devoted 4.6 hours to the flipped classroom (visualization of the videos, answering the questionnaires, solving the exercises…), a time that is found by 71% of them larger than that required by traditional teaching. These refusing opinions seem to be in accordance with other works in the literature (Missildine et al., 2013). Some students are used to traditional teaching because it is *comfortable* and it does not require so much implication and work due to the prominent role played by the instructor. In fact, students' motivation and engagement can even be reduced within this kind of active methodologies because they do not have totally accepted their new prominent role as leaders of their teaching–learning processes. As a result, students complain about the homework overload and the lack of detailed theoretical explanations in the classroom sessions (Pablo-Lerchundi et al., 2019).

Laptops were the connection device used more frequently. Moreover, 94% of the students remarked on the necessity of visualizing the videos more than once in order to better understand the explained concepts, while 49% of them resorted to other materials such as on-line documents or virtual platforms like YouTube.

Overall, students believe that the flipped-classroom experience has been adequate and that it helps in their learning process.

11.4.2 Teaching Kinematics of the Rigid Solid Within Other Contexts

Before concluding, let us compare the results reported in Sect. 10.4.1 with the performance of the students in the two previous academic terms. For this purpose, we first compare the 2021–22 results with the partial-exam marks of the 2019–20 academic term, when the teaching–learning process of KRS was conducted through traditional (on-site) master classes. Second, we compare the 2021–22 results with those obtained in the 2020–21 academic term, when the flipped-classroom methodology was introduced for the first time in our subject, but the teaching was completely on-line due to the COVID-19 pandemic restrictions.

Comparison between the flipped-classroom method and traditional teaching

To begin with, let us compare the qualifications listed in Table 11.6 for all the exam exercises of the 2019–20 and 2021–22 academic terms. This table lists the average marks for each of the four exam exercises along with their standard deviations. The value of the squared regression parameter has been included in order to quantify the correlation between each of the exercises on the global qualification in the partial exam. Nevertheless, certain differences can be observed in the marks for the individual exercises. As can be seen, the exercise on point kinematics increases from 1.4 points in the 2019–20 academic term to an average value equal to $\sim$2.9 for 2021–22, when the examinations consisted of two exercises on this topic instead of just one. Contrary, the average mark for the relative-motion exercise reduced from 4.3 to 1.8 points. Let us note that the 2019–20 exam included an additional exercise on point dynamics that was not considered in the 2021–22 exam (nor in that of 2020–21).

The KRS exercise was the one developed using different methodologies (traditional teaching in 2019–20 vs flipped classroom in 2021–22). Nevertheless, this difference seems to have had no influence on the exam qualifications (4.5 vs 4.2). The comparison of Tables 11.4 and 11.7 shows that some differences in the marks can be observed for the different questions conforming to the KRS exercises associated with the flipped-classroom activities and with the exam. For example, the performance on the calculation of the velocity of one point (Q_1) was better in 2021–22 than in 2019–20 (7.2 vs 6.3), while the computation of the invariants was more poorly answered (5.0 vs 3.4). Yet, due to the large standard deviations, all these results are compatible, i. e., they are not statistically different.

Table 11.6 Average marks μ and standard deviations σ for each of the exercises of partial exams conducted over the 2019–20, 2020–21, and 2021–2022 academic terms, along with their average values. R^2 is the squared regression parameter that characterizes the dependence of the averaged results as a function of the results for each exercise. All results have been normalized to 10 points

Exercise	2019–20			2020–21			2021–22		
	μ	σ	R^2	μ	σ	R^2	μ	σ	R^2
Kinematics of point 1	1.4	2.1	0.33	3.1	3.8	0.54	3.3	3.1	0.56
Kinematics of point 2	–	–	–	2.6	2.8	0.51	2.5	2.2	0.71
Kinematics of the rigid solid	4.5	3.3	0.57	3.6	3.3	0.64	4.2	2.8	0.77
Relative motion	4.3	3.7	0.65	1.8	2.6	0.47	1.8	2.6	0.67
Dynamics of the point	1.9	2.3	0.46	–	–	–	–	–	–
Exam average	3.0	2.8	–	2.8	3.1	–	3.0	2.1	–

Table 11.7 Same as Table 11.4 for the 2019–20 exam exercise on the kinematics of the rigid solid

	μ	σ
Q_1	6.3	4.5
Q_2	4.3	4.1
$Q_3 + Q_6$	5.0	4.2
$Q_4 + Q_5$	3.9	4.0
$\bar{x}$	4.5	3.3

Overall, the efficiency of the flipped classroom might look at first glance negligible. Notice, nonetheless, that the percentage of students that pass the exam in 2021–22 is larger for those who have followed the flipped classroom than for those who have not. Another important aspect to take into account is that the flipped classroom is regarded as a positive methodology, which enables more efficient use of the on-site lessons, as inferred from the satisfaction survey discussed next.

Comparison with the flipped-classroom experience during COVID-19 pandemic

As mentioned above, the teaching–learning process was virtual during the 2020–2021 academic term due to the COVID-19 pandemic. In general, the performance of the students in the questionnaires is comparable with those obtained in the 2021–2022 academic term: the average marks and dispersions for all questionnaires are similar (see Table 11.6 and Refs. (Ruiz-Galende et al., 2021a; Ruiz-Galende et al., 2021b)). In both cases, the students who performed better in the flipped-classroom activities got better qualification in the exam. However, there is a very important difference: the participation. While the flipped-classroom questionnaires were on average filled out by 28% of the students in the 2020–2021 academic term, in 2021–22 this percentage of participation increased up to 60%. In other words, almost twice of the students (in %) get engaged in the continuous assessment of the subject. This difference becomes strongly visible when comparing the optional (on-line) exercises that the students could do to get extra points. In 2020–21 only 3 out of 25 students (12%) did them,

Table 11.8 Same as Table 11.4 for the 2020–21 academic term

	μ	σ
Q_1 ($V_{2\text{–}6}$)	5.9 (3.8)	4.4 (3.7)
Q_2 (V_7)	2.8 (6.5)	3.9 (2.8)
$Q_3 + Q_6$ (V_8)	2.5 (4.0)	2.5 (2.4)
$Q_4 + Q_5$ (V_9)	1.8 (2.7)	2.3 (2.2)
$\bar{x}$	3.6 (3.3)	(2.3)

getting very poor qualifications. Contrary, in the 2021–22 term, 19 students (28%) did at least one of them. Different studies reported a decrease in students' motivation during home confinement, educational centers closures, and distance learning as restrictive measures adopted to contain a worldwide health emergency. Decrease in students' participation in extracurricular activities was associated with changes in academic motivation (Tan, 2021; Zaccoletti et al., 2020).

Similarly, the individual-exercise marks do not change much from the totally on-line context of 2020–21 to the 2021–22 situation. Nevertheless, the marks for the KRS exercise are different, both for the flipped-classroom activities as well as for the exam exercise, as concluded by comparison of Tables 11.4 and 11.8. In general, the qualifications are better for the 2021–22 *normal* academic term than for the 2020–21 *pandemic* one. Despite the large dispersion in the data, this result seems to indicate that the context of the pandemic (when the learning-teaching process had to be adapted to a totally on-line context) has much more importance on the student's performance than the flipped-classroom methodology (though the average marks for the remaining exercises stay more or less constant).

A more detailed comparison between the results for the *traditional on-site* 2019–20 and *flipped on-line* 2020–21 academic terms can be found in Refs. (Ruiz-Galende et al., 2021a, 2021b).

11.5 Final Remarks

In this chapter, the application of the flipped classroom for Physics teaching in the 2021–22 academic term has been reported. The experience was conducted with those first-year university students of the Degree in Agroenvironmental Engineering who were enrolled in the *Physics I* module. The flipped classroom was implemented in the teaching–learning process of the unit on the kinematics of a rigid solid.

We have observed that the performance of the students does not change much when learning through the flipped classroom or within a more traditional teaching based on master classes. In fact, if we compare the results obtained in the 2019–2020 academic term, they are better than those obtained in the following years when the flipped-classroom methodology was applied. Nonetheless, the comparison of the results for the 2021–2022 academic year with those obtained during the 2020–21

academic year shows some differences in the flipped-classroom efficiency, being the results better in the second year of application of the new methodology (2021–2022).

Moreover, it can be observed that within the peculiar circumstances of COVID-19 (on-line teaching, few personal contacts among the students, etc.) the performance of the flipped classroom is more limited, something that is reflected in the students' qualifications both in the flipped-classroom activities as well as in the exam. Contrary, the rest of the units seem to have been less affected by the COVID-19 pandemic.

The opinion of most of the students is positive regarding the used methodology, especially due to the better use of the teaching sessions, though they still prefer traditional (face-to-face) teaching.

Although we cannot assess that the methodology improves the learning process, with all the obtained results, we can consider it as a proper tool to achieve it.

Acknowledgements This work has been supported by the Universidad Politécnica de Madrid under Contract of Innovative Education No. IE1920.2002, IE22.2009, and APS22.2003.

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Chapter 12
Global Indicators for Measuring the Learning of the Active Students

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Abstract Education 4.0 is a model to meet the demands of Industry 4.0. This is achieved by developing competencies during the learning process that will later be used in Industry 4.0. The structural model proposed in this work has four components: Cloud Computing infrastructures (applied in the COVID-19 confinement period), active hybrid methodologies (applicable in face-to-face, online, and blended learning mode), technologies (through a technological ecosystem), and horizontal 4.0 competencies. One of the main factors differentiating industrial innovation from educational innovation in teaching is its scope. While the scope of industrial innovation is global (market sector), that of educational innovation in teaching is local (in the subject itself). This approach has several effects on educational innovation in teaching compared to industrial innovation: there is a great deal of repetition of experiences, the advances are not immediately incorporated into other educational contexts, and the impact is local. This paper analyzes evidence to rethink the scope of educational innovation in teaching, developing it under a global vision but applying it locally. The study was carried out utilizing a survey of teachers from different educational levels (university and non-university) and different countries. They were asked about the impact of student inactivity on learning and the indicators that, in their opinion, allow measuring the success of educational innovation to promote active learning. The responses indicate that the education sector has a shared vision of the impact of inactivity on learning and of the measurement indicators. The conclusion is that

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F. J. García-Peñalvo et al. (eds.), *Trends on Active Learning Methods and Emerging Learning Technologies*, Lecture Notes in Educational Technology,
https://doi.org/10.1007/978-981-19-7431-1_12

innovation applied to a specific academic subject can be approached globally across the entire education sector.

Keywords Active methodologies · Active learning · Educational innovation · MOOC

12.1 Introduction

Educational innovation in teaching can be considered an idea that produces a planned change in processes, services, or products that improve learning objectives (Sein-Echaluce et al., 2014, 2017). In the industrial sector, the OECD indicates that a characteristic of innovation is that the product, process, service, or method is new or significantly improved (OECD & Statistical Office of the European Communities, 2005; OECD & Eurostat, 2018).

From the point of view of the innovation catalyst, more emphasis is placed on the words change and improvement in the educational sector, while in the industrial sector, more emphasis is placed on novelty. Actually, both approaches are compatible since innovation in the educational sector is also done by introducing a novelty, usually methodological or technological.

In the industrial sector, incremental innovation incorporates already existing products with slight modifications (Mugge & Dahl, 2013). This innovation is based on the use of products, services, or technologies that are typically incorporated with minor modifications in each business sector. This type of innovation is widely used in small and medium-sized companies (Sancho, 2007), mainly because it is an innovation that is easy to apply, immediate, and can achieve more competitive and profitable growth for these companies (Bhaskaran, 2006).

This type of innovation is the one that is usually used in educational teaching innovation since it is based on the use of new technologies, new processes, or methods adapted to the context of a subject.

Thus, from the innovation catalyst (novelty) and the type of innovation (incremental), there is no difference between innovation applied in the educational sector and specific industrial sectors.

However, there is a big difference in the scope of innovation. In the industrial sector, the innovation of a particular product has the mission of introducing it into the market (OECD & Statistical Office of the European Communities, 2005), and if it is a service, this will result in an increase in profit and better sales (OECD and Eurostat, 2018). It can be affirmed that there is a global vision since innovations in this sector are carried out globally and with a competitive purpose. Business competitiveness and innovation are closely related (Acuna-Opaz & Castillo-Vergara, 2018).

This global and competitive vision of industrial innovation is what conditions the very characteristics of global innovation:

- There is novelty over what exists in the market. Therefore, there is no repetition of innovations, or it is minimal since if it is repeated, it is no longer considered innovation (OECD and Eurostat, 2018).
- The sector's demands (Schmookler, 2013) and needs (Infante-Moro et al., 2020) act as drivers and set the path for industrial innovation.
- User profiling studies (Landau & Rosenberg, 1986) are necessary to know the target audience of the innovation and to study the value it will bring them (Moncada et al., 2019).
- Specialized human resources are needed (Møen, 2005).

However, educational innovation in teaching does not have a global or competitive scope. Its scope is minimal since it is applied to the context of a specific subject. Therefore, the target audience can range from a few dozen people to one or several hundred. Thus, the scope of educational innovation in teaching is local. Nor is the objective to be competitive with other subjects since the impact of the innovation is focused on the subject. All these conditions the characteristics of teaching innovation:

- The lack of globality in the subjects leads to a significant repetition of work since the novelty of the product, service, or process is only applied within the scope of the subject and therefore has been previously involved in other subjects.
- The decision to innovate in the subjects is not competitiveness or obtaining economic benefits. The motivation is vocational, and the teachers themselves decide to innovate. Thus, this decision is not determined by social or sectoral demands. In industry, motivation is usually competitive, and the company makes decisions.
- The company entrusts the innovation to qualified personnel. In the case of teaching innovation, the teaching staff does not usually have qualified preparation in teaching innovation.
- There are also no user profile studies since the course students are the target of the teaching innovation.

All these characteristics mean a high repetition of innovation work, that the progress of innovation itself is plodding, and that innovations are not incorporated in the sector (in other subjects).

If educational innovation in teaching were global in scope, the needs of the product or service could be determined by the educational sector itself at a global level and could be aimed at a specific user profile.

The approach of this article is that educational innovation in teaching can be approached globally and not locally. To this end, it is hypothesized that there is globality in the profile of the target audience for educational innovation in teaching, that the sector demands specific improvements, and that the results can have a global scope.

To study the hypotheses, we focused on a specific aspect such as the active participation of students in a subject to improve their learning, since this uses more cognitive abilities, in addition to the merely auditory (Dewey, 1916; John, 1929), that passive students usually use (Fidalgo-Blanco et al., 2021).

Some classical authors have identified indicators that allow us to know if the student body is creating knowledge from existing knowledge (Piaget, 1964), interaction among students (Vygotsky, 1978), social interaction (Ausubel, 1969), and cooperation (Paavola & Hakkarainen, 2005).

Indicators of the importance of active participation in learning are the new methods that have emerged (Alonso de Castro & García-Peñalvo, 2022; Conde-González et al., 2014), such as the Flipped Classroom, which improves the active participation of students by taking certain learning activities out of the classroom beforehand (Fidalgo-Blanco et al., 2017; Khailova, 2017). Challenge-based learning (Conde et al., 2017) can also be considered a recent methodology to improve active (García-Peñalvo et al., 2019) and cooperative learning participation (Fidalgo-Blanco et al., 2016), as well as gamification (Llorens-Largo et al., 2016), where students learn with motivational techniques that are often used in games (Johnson et al., 2006; Morales Carbajal & Villa Angulo, 2019).

Thus, as the improvement of active participation continues to be relevant, this is the starting point for this work.

Previous works showed that at different educational levels and in different countries, there is a shared vision of the profile of the students to whom the innovation is addressed and, therefore, innovation with a global target audience could be proposed (Fidalgo-Blanco et al., 2019a, b).

In this research, we will analyze whether at different educational levels and in different countries there is a shared vision on how the improvement of active participation in learning would be affected. If this vision were common, it would demonstrate that the sector is demanding this innovation. Whether there is a common vision of the indicators that can measure active student participation will also be analyzed. The same innovation could be applied to different subjects if this vision is shared. This would mean that the teaching innovation could be approached globally and therefore could open the way to reduce the problems identified regarding teaching innovation.

12.2 Model

The applied model is based on the method MAIN (Method for the Application of Educational Innovation) (Fidalgo-Blanco & Sein-Echaluce, 2018; Fidalgo-Blanco et al., 2018). This method is designed to achieve that educational innovation has the characteristics of good practice of educational innovation: effectiveness, efficiency, sustainability, and transferability. It consists of four phases, three (phases 1, 2, and 3) are sequential, and one (phase 4) is carried out in parallel.

The mission of each phase is as follows:

- Phase 1. Identification of the root problem. The final mission is to obtain a set of measurable indicators that define the achievement of the learning improvements

that teachers wish to introduce in their subjects. In addition, the formulation and steps taken in this phase allow defining a global scope of the innovation to be carried out.

- Phase 2. Identify the most appropriate method of educational innovation in teaching. The final mission is to identify teaching innovation methods with proven effectiveness in treating the measurable indicators chosen in the previous phase. One of the chosen methods will be selected.
- Phase 3. Customize the innovation method to the context profile. The context is defined by the teaching staff, the subject (type, knowledge area, course, etc.), and the students. The mission is to disassemble the innovation method chosen in the previous phase and reassemble it, adapting it to the specific context. In this case, what was previously designed globally is applied locally.
- Phase 4. Strategy to generate a good practice and publish it in scientific contexts. This phase is carried out in parallel and guarantees that the experience to be developed is effective, efficient, sustainable, and transferable. Likewise, the procedures for measuring, contrasting, and correlating the indicators with the learning outcomes are developed.

In Phase 1, to facilitate obtaining the indicators that allow the achievement of the proposed improvements to be assessed, a series of steps are carried out as follows:

- Step 1. Identify the root problem and the learning improvements that could solve the problem. In this research work, the root problem is the passivity of the students. Therefore, the improvements intended to be achieved are based on the active participation of the students in the subject.
- Step 2. Identification of the target audience. The characteristics of the students who present the root problem are identified. In this case, the characteristics of passive students are identified. This step is critical for the research since the result provides the data that will be analyzed in this work.
- Step 3. Identification of sector needs. The consequences of the root problem on learning are identified. In this case, the consequences of student passivity on learning are identified. In this way, the real need of the education sector to solve the root problem is being defined.
- Step 4. Identification of indicators. Quantitative, qualitative, and mixed measurable indicators are identified. These indicators are associated with the improvements to be achieved and check whether the root problem has been solved. Their identification is easier if it is done through the results of phases or steps 2 and 3.

Step 2 is the main object of this research. The procedure followed in this step is as follows:

- Teachers are asked to think about their students and indicate which observable patterns indicate that they are passive learners from their point of view.
- Teachers are asked to describe a maximum of three characteristics of this passive learner.
- It is shared among the teaching staff, and a common sharing is carried out.

This process has been carried out in previous research work. Seven sessions were held with six Spanish universities and four Latin American universities. From the fourth session onwards, indicators different from those presented in the previous sessions were no longer specified.

The measurement tool for this research work is a survey. This survey collects the different indicators obtained through the open process of the previous research work.

12.3 Context

This work has been carried out with the participants in the second edition of the MOOC "Flip Teaching: An Active Methodology". The course was taught on the Miriadax platform from June 16, 2019, to July 14, 2019. The course duration was five weeks and a total of 35 teaching hours. The course was started by 1,099 persons and completed by 377 persons.

The information collected by the MiriadaX platform itself on participants by country is presented in Table 12.1. This table shows the top 10 countries with the highest participation.

The survey was carried out before starting the course, during module 0, where the structure and methodology of the course were explained. Out of 943 participants in this module, the survey was carried out by 497 people; that is to say, the survey was carried out with a sample of 52% of the participants.

For n = 497, the gender of the participants was 61.7% female and 38.83%, male. Table 12.2 shows the percentage of participation of those who filled out the survey for the same sample, indicating the top 10 countries. Table 12.3 shows the percentages considering the highest level of studies completed by the participants. Table 12.4 shows the percentages according to the professional profile of the participants.

Table 12.1 Percentage of participation in the MOOC by country, according to MiriadaX

Country	Percentage
Spain	33.13
Mexico	13.28
Ecuador	9.44
Peru	9.33
Colombia	6.56
Argentina	4.97
Chile	3.17
Venezuela	3.11
Brazil	2.43
Bolivia	1.70

Table 12.2 Top 10 countries in percentage of participation of those who completed the initial survey

Country	Percentage
Spain	34.31
Mexico	16.90
Ecuador	12.07
Colombia	6.04
Peru	4.83
Argentina	4.83
Venezuela	3.82
Chile	2.41
Dominican Republic	2.41
Bolivia	2.21

Table 12.3 Highest academic degree completed

Highest academic level completed	Percentage
University education degree	49.09
University education master's degree/doctorate	41.85
Vocational training	6.24
Secondary education	2.82

Table 12.4 Professional profile of the participants

Professional profile	Percentage
Non-university teacher (students 12–18 years old)	30.18
University lecturer	29.38
Vocational training teacher	12.68
Non-university teacher (students up to 12 years old)	8.45
Self-employed	7.44
Non-teaching employee	6.24
University student (education area)	3.62
University student (non-education)	1.41
Non-university student	0.60

12.4 Results

Four hundred ninety-seven people carried out the survey, but 401 of them have a teaching profile. Therefore, the analysis work is carried out on 401 responses, representing 80.68% of the sample.

Question Q8 measures the negative impact of the absence of student activity on their learning. It comprises a series of items measured on the Likert 4-scale.

The questions were obtained from a list of answers given by professors from different Spanish and Latin American universities (Fidalgo-Blanco et al., 2019a, b). Table 12.5 shows the list of items corresponding to this question.

The averages of the responses obtained for the ten most valued questions on the list for each educational level are shown below: teachers with students up to 12 years of age (Table 12.6), teachers with students between 12 and 18 years of age (Table 12.7), teachers with students in vocational training (Table 12.8), and university teachers (Table 12.9).

From the analysis of this result, it can be observed that there is an 80% coincidence of the negative impact of the absence of active learning on learning at all educational levels.

If we compare the opinion of university professors with that of students between 12 and 18 years of age, the coincidence is 90%.

Table 12.5 List of items from question Q8

He/she learns only what he thinks will be helpful for the exam
He/she passes on their passive attitude to their classmates
Teachers need to make an extra effort since it is not easy to detect if the students have understood what has been explained
Teachers cannot finish the syllabus
Teachers are thinking of changing the teaching methodology
He/she is demotivated
He/she tries to learn only by memorizing
He/she needs more time or does not understand basic concepts
He/she does not acquire or improve competencies such as analytical skills, synthesis skills, critical capacity, commitment to group work, leadership, self-learning, work habits, etc
He/she does not show initiative
He/she does not know how to value his/her own abilities
He/she does not get involved in his/her own learning
He/she does not have intrinsic motivation
He/she does not have a practical vision of the subject
He/she obtains poor academic results
He/she causes an increase in the school failure rate in the subject
He/she causes demotivation in the teaching staff
He/she causes a decrease in the course's overall class attendance rate
He/she causes a decrease in the overall rate of participation in the course activities
He/she causes a decrease in the number of students taking the exam
He/she causes a decrease in the overall pace of class development
He/she causes problems in the work of the group
He/she disconnects from the follow-up of the course
He/she has difficulty in following the development of the class

Table 12.6 Answers Q8 given by teachers with students up to 12 years of age

Top 10 items question Q8	Average
He/she has no initiative	3.14
He/she lacks intrinsic motivation	3.12
He/she is disconnected from following the subject	3.07
He/she is unmotivated	3.05
He/she learns only what he/she thinks will help him/her for the exam	3.05
He/she does not get involved in their own learning	3.02
The teacher needs extra effort since it is not easy to detect if the student has understood what has been explained	3.02
He/she needs more time or does not understand basic concepts	3.00
He/she does not acquire or improve analysis capacity, synthesis capacity, critical capacity, commitment to group work, leadership, self-learning, work habits, etc	3.00
Teachers are considering changing the teaching methodology	3.00

Table 12.7 Answers Q8 given by teachers with students between 12 and 18 years of age

Top 10 items question Q8	Average
He/she is not involved in his or her own learning	3.17
He/she is unmotivated	3.13
He/she does not show initiative	3.12
He/she does not acquire or improve competencies such as analytical skills, synthesis capacity, critical capacity, commitment to group work, leadership, self-learning, work habits, etc	3.11
Teachers need to make an additional effort since it is not easy to detect if the students have understood what has been explained	3.09
The teaching staff considers changing the teaching methodology	3.09
He/she lacks intrinsic motivation	3.07
He/she does not know how to value their own abilities	3.04
He/she does not have a practical vision of the subject	3.03
He/she needs more time or does not understand basic concepts	3.02

The coincidence is 66.66% between the university and any other educational level if we analyze the first three indicators.

Question Q9 expresses the measurable indicators that would verify that students actively participate in the subject once the innovation has been implemented. It comprises a series of items measured on a Likert 4-scale. The questions were obtained from a list of answers given by professors from different Spanish and Latin American universities (Fidalgo-Blanco et al., 2019a, b). Table 12.10 shows the list of items for question Q9.

The ten most valued responses for each educational level are presented below. Table 12.11 shows the answers given by teachers with students up to 12 years of age,

Table 12.8 Answers Q8 given by teachers with students in vocational training

Top 10 items question Q8	Average
He/she is unmotivated	3.25
He/she learns only what he/she thinks will help him/her on the test	3.17
He/she is not involved in his/her own learning	3.16
He/she does not have a practical vision of the subject	3.13
The teachers are considering changing the teaching methodology	3.13
He/she does not know how to value their own abilities	3.11
He/she needs more time or does not understand basic concepts	3.10
He/she does not acquire or improve competencies such as analytical skills, synthesis skills, critical capacity, commitment to group work, leadership, self-learning, work habits, etc	3.08
He/she does not show initiative	3.06
He/she does not have intrinsic motivation	3.05

Table 12.9 Answers Q8 given by University teachers

Top 10 items question Q8	Average
He/she shows no initiative	3.15
He/she learns only what he/she thinks will be helpful for the exam	3.14
He/she does not get involved in his own learning	3.13
He/she does not acquire or improve competencies such as analytical skills, synthesis skills, critical capacity, commitment to group work, leadership, self-learning, work habits, etc	3.10
Teachers are considering changing their teaching methodology	3.10
He/she needs more time or does not understand basic concepts	3.08
He/she does not know how to value their own abilities	3.07
He/she lacks intrinsic motivation	3.06
Teachers need additional effort as it is not easy to detect whether students have understood what has been explained	3.03
He/she is unmotivated	3.01

Table 12.12 the answers given by teachers with students between 12 and 18 years of age, Table 12.13 the answers given by teachers with students in vocational training, and Table 12.14 the answers given by university teachers.

Of the first ten responses, 70% are common to all educational levels, and 80% are coincident with all areas except with teachers of students up to 12 years old. The highest percentage with the university is obtained with teachers of students between 12 and 18 years of age, which is 90%.

If we analyze the first three responses, there is a percentage of 66.66% at each educational level, although the order of the first two only coincides with the relationship between university and secondary school.

Table 12.10 List of items from question Q9

Increased cooperation in activities
Increase in initiatives and proposals
Increased attendance at tutorials
Increase in the degree of student satisfaction
Increase in the degree of satisfaction of the teaching staff
Increase the number of activities carried out, although they do not affect the final grade
Increase in the number of group work done
Teachers can adopt a coaching role
Increased class attendance
Bring prepared material to practice
More participation in debates
Increased assimilation of concepts
Greater learning autonomy
Easier to learn new topics
Increased number of students taking the exam
Better performance in subject-related topics
Improved punctuality to face-to-face sessions
Improved performance in group work
Improved analysis and synthesis skills
Raises doubts in different channels provided by the teaching staff
Prefers the use of active methodologies
Performs the activities in the established time or more quickly

Table 12.11 Answers Q9 given by teachers with students up to 12 years of age

Top 10 items question Q9	Average
Increased student satisfaction	3.33
Increased participation in discussions	3.33
Increased learning autonomy	3.29
Increased teacher satisfaction	3.29
Increase the number of activities carried out, although they do not affect the final grade	3.24
Increased cooperation in the activities	3.24
Improved group work performance	3.24
More accessible learning of new topics	3.24
Greater assimilation of concepts	3.21
Preference for the use of active methodologies	3.21

Table 12.12 Answers Q9 given by teachers with students between 12 and 18 years of age

Top 10 items question Q9	Average
Increased teacher satisfaction	3.39
Increased learning autonomy	3.33
Improved analytical and synthesis skills	3.33
Increased student satisfaction	3.33
Improved performance in subjects related to the subject matter	3.31
Teachers can adopt a coaching role	3.31
Improved group work performance	3.30
Better assimilation of concepts	3.30
Preference for the use of active methodologies	3.30
More participation in debates	3.28

Table 12.13 Answers Q9 given by teachers with students in vocational training

Top 10 items question Q9	Average
More participation in debates	3.24
Increased teacher satisfaction	3.24
Increased student satisfaction	3.21
Increased class attendance	3.21
Increased cooperation in activities	3.21
Improved group work performance	3.19
Preference for the use of active methodologies	3.19
Greater learning autonomy	3.17
Teachers can adopt a coaching role	3.17
Increase the number of activities carried out, although they do not affect the final grade	3.14

Table 12.14 Answers Q9 given by university teachers

Top 10 items question Q9	Average
Increased teacher satisfaction	3.53
Greater learning autonomy	3.49
More participation in debates	3.45
Increased assimilation of concepts	3.44
Increased student satisfaction	3.43
Improved analysis and synthesis skills	3.43
Teachers can adopt a coaching role	3.43
Preference for the use of active methodologies	3.42
Increased cooperation in the activities	3.42
Improved group work performance	3.41

12.5 Conclusions

Educational innovation in teaching has similar approaches to industrial innovation in terms of including something new and the method of incremental innovation used. The big difference is in the scope and results. While industrial innovation advances based on the latest existing innovations, has a global impact, and is quickly adopted by the sector, educational innovation in teaching has a great deal of repetition of work, is not based on the latest innovations, and is not quickly adopted by the educational sector.

The main difference is the approach to innovation. While in-industrial innovation is done with a global or sectoral approach, educational innovation in teaching is done with a local approach.

This work shows that the focus of educational innovation in teaching can change from local to global. It has been demonstrated that there is the same perception of the sector's needs in different educational environments, identifying the problems that exist for a particular student profile and identifying the indicators that would demonstrate that the innovation has been successful.

The degree of coincidence in the problems, for the ten main problems, is 80% in all academic areas, while for the improvement indicators, it is 70%. This degree of coincidence rises to 90% for both the problems and the indicators for measuring improvement in the case of university teachers and students between 12 and 18 years of age.

Acknowledgements This research was partially funded by the Spanish Government Ministry of Economy and Competitiveness through the AVisSA project grant number (PID2020-118345RB-I00). The authors would like to thank the research groups EtnoEdu of the University of Zaragoza, GRIAL of the University of Salamanca, and LITI of the Technical University of Madrid for their support.

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