



# Building learning from brain knowledge

## Construyendo aprendizaje a partir del conocimiento

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### HIGHLIGHTS

- Learning takes place through the connection between neurons.  
El aprendizaje tiene lugar a través de la conexión entre neuronas.
- Based on this concept of deep learning, a discussion opens about the best time and the best way to evaluate the effectiveness of the innovations that are conducted in the classroom.  
Basado en este concepto de aprendizaje profundo, se abre una discusión sobre el mejor momento y la mejor manera de evaluar la efectividad de las innovaciones que se llevan a cabo en el aula.

## RESUMEN

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La base de la experiencia educativa presentada se fundamenta en la neuroeducación, que es la aplicación de la neurociencia y la psicología cognitiva a la educación. A través de la aplicación de las metodologías activas Aprendizaje Basado en Proyectos y Aprendizaje Invertido, se diseña una estrategia didáctica en la que los estudiantes deben llevar a cabo un proyecto de ejecución de construcción durante el desarrollo de la asignatura Sistemas Constructivos I del Grado en Fundamentos de Arquitectura. Los resultados muestran calificaciones satisfactorias en relación con el número de estudiantes presentados, si se considera la complejidad de la materia. La principal conclusión obtenida es que la combinación de estas dos metodologías, aplicadas de acuerdo con los principios de la neuroeducación, favorece la adquisición de conocimientos de contenidos de construcción.

**Palabras clave:** *Neuroeducación, proyecto basado en aprendizaje, aprendizaje invertido, sistemas constructivos, proyecto de implementación .*

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## ABSTRACT

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The basis of the educational experience presented is based on neuroeducation, which is the application of neuroscience and cognitive psychology to education. Through the application of the active methodologies Project Based Learning and Flipped Learning, a didactic strategy is designed in which the students must conduct a construction execution project during the development of the subject Building Systems I of the Degree in Foundations of Architecture. The results show satisfactory grades in relation to the number of students presented, if the complexity of the subject is considered. The main conclusion obtained is that the combination of these two methodologies, applied according to the principles of neuroeducation, favors the acquisition of knowledge of construction contents.

**Keywords:** *neuroeducation, project-based learning, flipped learning, constructive systems, implementation project*

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## 1. INTRODUCTION

There is an increasingly widespread and internalized conception that the success of the teaching/learning process depends on the active participation of teachers and students. Some of the classic pedagogical models, such as constructivism, postulate that knowledge is acquired through practice and the student's own experience. Today, thanks to neuroscientific research applied to education, known as neuroeducation, not only has this statement been proven to be true, but also important questions related to the way the brain learns have been revealed. Neuroeducation is a

scientific knowledge that integrates psychology, sociology, and medicine to improve teaching/learning processes [1]. At a time when students are surrounded by technologies, dynamics and habits that are increasingly distant from the way their teachers were trained, it seems important to turn to this discipline to maximize their learning. The aim is to create learning situations that meet the demands of society [2] in general and of architecture students in particular.

One of the formulas that neuroeducation proposes to achieve these learning experiences is the use of active methodologies, such as

Project Based Learning (PBL). Projects, especially if they are related to real situations, allow learning the contents and developing skills such as autonomy and critical reflection [3]. Another method that leads to an improved learning experience is flipped learning (FL). Neuroeducation confirms that each brain is unique and learns in a different way and at a different pace. The level of complexity of technical teaching sometimes prevents all students from grasping and understanding concepts at the same time as they are being explained in a lecture in the classroom. The FL encourages each student to follow his or her own pace of learning. In disciplines related to architecture and construction, there are several experiences that show that, through FL, students are more motivated to acquire knowledge [4], as it allows them to access content from anywhere and at any time [5].

In fact, both PBL and FL have been recurrently used in construction subjects in different schools of architecture and building. Proof of this are some of the experiences published in the Conference on Teaching Innovation in Architecture (JIDA) by teachers from the País Vasco University [6], Valencia Polytechnic University [5] and Málaga University [7], as well as those from the Extremadura University [8] and Madrid Polytechnic University [9] published in previous editions of this International Congress on Educational Innovation in Building (CINIE).

Following these lines of research in education, the aim of this paper is to show a didactic strategy designed based on the knowledge of neuroeducation, based on a combination of PBL and FL, in order to build learning in students. To do so, we proceed to explain the strategy, justifying the contributions of neuroeducation that have been used to conduct each action.

## **2. MATERIALS AND METHODS**

The didactic strategy, programmed for the subject Building Systems I of the Degree in Foundations of Architecture, is set out following seven sequenced actions that form part of a cycle designed in a proposal [10] based on the Biggs [11] and DIDEPRO [12] models. The phases are: context, objectives, approach, planning, teaching, evaluation, and improvement. It is important that there is coherence between them, as well as between the objectives, contents, methodology and evaluation of the subject.

Each of these is described below, although the improvement actions have been placed at the end of the discussion section.

### **2.1 Context**

Within the training itinerary of the Degree in Fundamentals of Architecture in which the practice is contextualized, there are only two four-month subjects of 6 ECTS that deal directly with the contents of construction. One is taught in the second year and the other in the third year. Both subjects focus on providing knowledge and analysis of the different construction systems that form part of a building and how this condition both its design and its operation. With the environment in mind, students are guided so that construction contributes to facilitating maintenance, increasing the useful life and reducing the ecological footprint of buildings. The present experience is developed in the same way for two groups in the second-year course. The number of students in each group varies from year to year, but there are usually between 70 and 80 students in group 1, and between 50 and 60 in group 2. This is the first time the students have taken a construction subject, although they do have a basic knowledge of architectural representation and building materials.

The contents covered are related to the construction process using conventional systems. It begins with some notions on demolitions and previous actions and continues with the main chapters of the work, in approximate order of execution: earthworks, foundations, horizontal drainage network, structures, façade and roof enclosures, interior partitions, wall, ceiling and floor finishes, and urbanization. These contents are studied in the same way as the construction part of the execution projects: analysis of current regulations, determination of materials and construction solutions, definition of the final solution, and drafting of specifications and plans [6].

Prior to the 2019/2020 academic year, the subject was taught in the classroom through a combination of theory and practical sessions with PBL as the common thread. Due to the necessary adaptations in 2020, the content began to be developed using videos, which were used to include the FP methodology in the dynamics of the subject and to dedicate the classroom sessions to deepening the content and working on the project. In subsequent years, more educational videos have been produced, so that the methodologies currently applied are PBL and FL.

## 2.2 Objectives

The main objective of the didactic strategy is to make students aware of how a building is constructed, from start to finish, using conventional techniques. This objective leads to an understanding of the concept of the constructed building and an awareness of the importance of the construction systems and building materials chosen to meet the requirements of stability, airtightness, thermal and acoustic envelope.

Learning takes place through the connection between neurons. When you have creative thoughts, which involve questioning, recognizing patterns hidden in plain sight, critical and analytical observation and connecting seemingly unrelated elements [13], learning is taking place. In this line, the intention is that students are able to create their own constructive solutions by investigating in order to make the right decision.

## 2.3 Approach

The course is developed around the teaching methodologies mentioned above: FL and ABP.

Flipped Learning follows a model whereby students consult and study the contents before attending class, so that during the sessions they can assimilate and understand them through activities guided by the teachers (Fig. 1). In this way, the brain is encouraged to transform the content (what is taught) into knowledge (what is learned) [14].

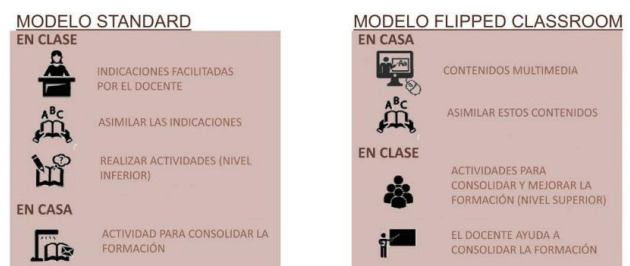
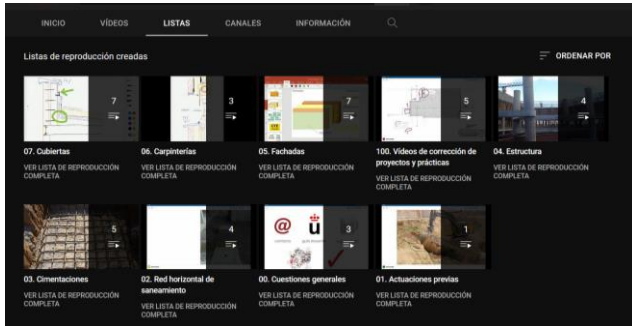


Fig. 1: Diagram of the standard teaching model compared to the flipped classroom model (Source: Rizzo [et.al.], 2015).

The basic contents of the course are provided on the first day of the course in various formats: notes, general execution plans, construction detail sheets and didactic videos. The videos are published on a YouTube channel, classified into nine playlists (Fig. 2). Two of them contain videos on general issues and correction of previous years' projects, and the other seven are about the contents themselves. Each content list has a

first video with a slideshow on the general issues of the chapter, and several videos in which construction details associated with the corresponding chapter are drawn and explained.



**Fig. 2:** Presentation on the YouTube channel of the playlists with the contents of the subject.

While watching the videos, the students take notes on the main considerations, those that catch their attention and any doubts that arise. All of this is recorded in their construction portfolios, which are complemented with the questions dealt with in the classroom sessions. The portfolio is not limited in format or length. The aim is to provide them with their own material that they can consult both in the rest of the subjects and, later on, in their professional career. These two actions, which are customized to the pace and methods of each student, favor their intellectual effort, boosting their brain activity and knowledge acquisition [14], as well as developing competences related to self-learning and self-knowledge.

PBL is a methodology that allows students to learn in an active, constructive and creative way [15]. There are previous experiences of using PBL in construction subjects that have been positive and effective because a real execution project is proposed [6], as proposed in this experience. The students have to solve a written and a graphic part. The written part consists of a descriptive report, justification of the current regulations of the Structural Code (CE) and the Technical Building Code (CTE) and the

execution process ordered chronologically. The graphic part is made up of general plans and construction details, which are represented by hand in din-A3 format.

Each student has to carry out the execution project for a single-family dwelling with two floors above ground level, with at least one party wall and an exterior plot area. The teacher provides a statement with the floor plans, elevations and sections of the building, as well as a set of construction systems that can be used. Some of them are imposed, such as the foundations, structure and roofs, and others can be chosen, such as the façades, partitions and finishes at the student's discretion. The statement is identical for all students, except for the location, which is chosen by each one of them, within the Spanish territory, so that they can look for the parameters of the CE and the CTE for their city. In construction, there are always several solutions that can respond to the same situation. One of the most important actions in the creative process, which is fundamental for the brain to learn, is the ability to identify problems and opportunities [16]. Hence, each student can decide which materials and construction systems are most appropriate for his or her project, within, of course, limitations adapted to his or her knowledge.

## 2.4 Planning

At the beginning of the course, students are given a schedule of all the sessions, indicating, for each day, the contents to be worked on, the didactic material they need, the work to be done in the classroom and the video(s) they should bring with them to watch (Fig. 3). It is important that they have this schedule from the beginning, so that they can organize their autonomous work with a view to the project checkpoints, which are also reflected in the schedule.

	FEBRERO		MARCH		APRIL		MAY	
	MIÉRCOLES 7	VIÉNEVES 8	MIÉRCOLES 14	VIÉNEVES 15	MIÉRCOLES 21	VIÉNEVES 22	MIÉRCOLES 28	VIÉNEVES 29
Contenido	¿Qué sabemos? ¿Qué queremos aprender? ¿Cómo queremos aprender? Talleres de libro		Plano general, detalles constructivos, normativa, maquetación y simulación		Red horizontal de saneamiento		Cimentación	
Materiales didácticos	Resortes, Portafolios		Presentación + Plano de ejemplo + Detalles constructivos + CTE DB-H		Presentación + Plano de ejemplo + Detalles constructivos + CTE DB-C + Código estructural		Resortes, Portafolios	
Tareas de aula	Fuentes de investigación, Generador de precios		Raccos, Portafolios		Proyecto de ejecución de una vivienda unifamiliar		Toda la anterior + proyectos de ejemplo	
Temas video	CE2, SC2 Ejercicios constructivos		MT1, Actuaciones previas		SAH1, Red horizontal de saneamiento, Conceptos SAH2, detalles constructivos de arquetas		CMI1, Cimentaciones, Conceptos básicos CMI2, Detalles constructivos de zapata aislada con pilar de hormigón CMI3, Detalles constructivos de zapata combinada CMI4, Detalles constructivos de zapata corrida bajo muro de hormigón CMI5, Detalles constructivos de zapata para pilar de acero	

**Fig. 3:** Extract from the subject schedule for the month of February.

As this is a 6 ECTS course, the time is divided into two two-hour sessions per week over a period of 15 weeks. Every two or three weeks, depending on the content, there is a whole week devoted to project control and a hand-in associated with this control.

### 2.5 Teaching

The development of classroom sessions varies according to the planning. There are three types of sessions: work sessions, checkpoint sessions and sessions for getting to know the profession.

The work sessions are structured in three moments: general doubts, theoretical explanation and classroom work. The classes begin with rounds of doubts from the students about the information previously visualized and studied to clarify all those aspects that they have not understood. This is followed by a brief theoretical explanation in which either an important question about the concepts in the videos is explained in depth or a concept or construction procedure is added that is not reflected in the videos and that they will need for the development of the project. The duration of this explanation is about 20 minutes because attention is a limited resource that can only be sustained for short cycles of time [15]. After that, the brain needs processing and assimilation time to learn, so the rest of the class is spent solving the project. To give each student, the pace of

work they need and to encourage peer learning, three large groupings are created in the classroom, like corners. In each of them, students are arranged to work on regulations, general plans and construction details, respectively. Likewise, a space is left near the teaching staff, called simulation, where catalogues, books and construction parts are made available to students so that they can conduct the consultations and evaluates they need. Occasionally, the professors proposal some materials for the assembly some construction systems (Fig. 4)



**Fig. 4:** Simulation working corner for the horizontal underground sewerage network.

Project checkpoint sessions are usually double sessions, they are usually held on both days of the week. Depending on the needs of the group and the workload involved, they are organized in one way or another. Sometimes, general critical sessions are held on the solutions obtained, which allow different points of view and criteria to be expressed [17], as well as a debate on the possibilities that exist for tackling the same problem. At other times, peer review is used. Students are asked to exchange their projects and correct the project(s) of another partner(s). Afterwards, they sit down together to exchange impressions.

In both cases, it is made clear that both teachers and students should provide useful and positive feedback, as social approval causes the neural connections in the creative brain to be maintained and strengthened [13].

The approach to the profession is also an important part of the learning process. The importance of projects and case studies that are close to reality has been discussed above. Unfortunately, it is not easy to get the necessary permissions to visit construction sites. However, efforts are made to ensure that there are at least two sessions to get closer to the profession. Usually, one of them takes place at the university, with a visit from manufacturers or technicians, and the other one takes place by visiting a construction fair or an exhibition of construction solutions.

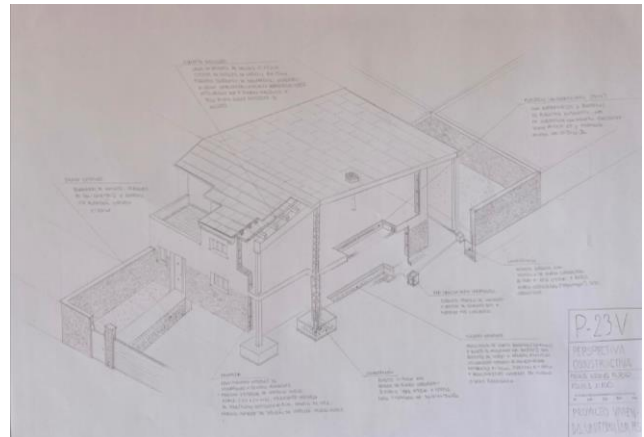
## 2.6 Evaluation

The assessment of the subject is continuous and formative. The teaching guide establishes three assessment tests, all of them of an individual nature: the construction portfolio, the execution project, and a complementary test.

The construction portfolio is a voluntary and non-assessable submission that counts for 20% of the final grade. Depending on the number of self-created notes, a higher mark is awarded.

The execution project is compulsory, re-evaluable and counts for 70%. There are three previous deliveries before the final delivery. It is assumed that the students have no previous knowledge of construction and that their solutions are therefore highly likely to be wrong. Therefore, after each correction, they are given a rubric with the qualitative scale: not achieved/under development/achieved for each evaluation item, which they know beforehand. They are also given the graphical part of their

project corrected by hand. In this way, the students can quickly identify the aspects they need to correct. With each partial delivery, they must provide the previous corrected version plus the new one. The grade is taken from the latest version of their project. They can also include additional details or constructive perspectives (Fig. 5).



**Fig. 5:** Construction perspective of the building solved by the student P.A. during the school year 2020/21.

In accordance with the contributions of [2] and López [18] on formative assessment, student participation in assessment processes is considered important. For this reason, the complementary test is agreed between teaching staff and students. In the 2021/22 academic year, this test consisted of a self-assessment of their own execution projects, for which they could obtain the remaining 10% of the total grade.

## 3. RESULTS AND DISCUSSION

The academic results are analyzed for the academic years 2020/21 and 2021/22. Although it is true that the ABP has been conducted for four previous academic years, it had not been combined with the FL and, furthermore, the 2019/20 academic year is not representative as more than half of the academic period has been spent in confinement.

Table 1 shows the results, by percentages, for each of the groups and type of official qualification. It can be observed that, in both groups, there is an elevated level of students who did not submit their projects, although this percentage has decreased in the 2021/22 academic year.

The sum of the values of non-submitted and failed students is around 46%, except in year 20/21 in group 2, which amounts to 62.79%. In all cases this is approximately equivalent to the percentage of students who do not attend the sessions frequently.

The results also show that there is a high percentage of Bs and A's, compared to the percentage of passes. This is mainly in those cases where students have corrected their mistakes after the partial deliveries to obtain more accurate solutions.

In group 1 the grades are higher, although this is not significant when compared with the results obtained in the other subjects of the Degree.

**Table 1** Grades for each group in the last two grades.

Rating	Group 1		Group 2	
	2020/21	2021/22	2020/21	2021/22
MH	1,52%	2,53%	2,33%	2,08%
SB	9,09%	7,59%	4,65%	2,08%
NT	19,70%	22,78%	18,60%	18,75%
A	24,24%	25,32%	11,63%	29,17%
S	13,64%	17,72%	4,65%	8,33%
NP	31,82%	26,58%	58,14%	39,58%

As for the qualitative results, it is difficult to know the knowledge that the students have retained, although it is true that the teachers who teach Construction Systems II, as a continuation of this, state that the students arrive, in general, with a good basis. This issue is addressed in the discussion below.

### 3.1 Discussion of results

This paper demonstrates that it is relatively easy to design and teach a technical and complex subject based on neuroeducation and obtain

satisfactory grades. However, just by analyzing the numbers of the course they finish, it is difficult to know whether the students have acquired the knowledge, if they have learned in a meaningful and deep way. Ruiz [19] states that learning is deep when the knowledge acquired is lasting; transferable, insofar as it is applicable in contexts other than the one in which it was learned; functional, because it allows us to do things with it rather than just reproduce it; and productive insofar as it helps us to continue learning.

Based on this concept of deep learning, a discussion opens about the best time and the best way to evaluate the effectiveness of the innovations that are conducted in the classroom. Have students really learned deeply after applying neuroeducation techniques? How and when could we check this, beyond the grades? One option would be to assess the same knowledge in subsequent years, although, in that case, variables related to their new academic and professional experiences, if any, would have to be considered. Discussion on this issue is therefore left open, and readers are encouraged to investigate and share their findings on these questions.

### 3.2 Proposals for improvement

In view of the results, it can be affirmed that improvements should be aimed at reducing the percentage of students who do not present their project in any of the sessions. At the beginning of the course, attendance is quite high, and, after the first submission, motivation begins to diminish. Fernández-Bravo [14] states that the first phase in solving a problem is to want to solve it and that "there will be no learning that provides knowledge where there is no challenge that provokes a need to "want to do" in the learner" (p.14). Based on this, a possible solution would be to add intermediate



challenges to the project itself with an associated reward, or to include technology to model constructive solutions.

Another reason for dropping out of the subject comes from the constant work involved in developing a long-term project. As the course progresses, the work of other subjects starts to overlap, and students report that they find it difficult to keep up with the pace. A proposal for improvement would be to coordinate the delivery dates with the rest of the teachers on the course.

#### 4. CONCLUSIONS

After having conducted two complete courses combining the ABP and FL methodologies, it can be affirmed that it is an effective tandem that favors the knowledge of the contents of an initial construction subject. In subsequent courses, it is planned to continue with the same approach, incorporating the planned proposals for improvement, to continue building learning. One of the actions involved in educational innovation is the constant rethinking of the way things are done, with the intention of improving the quality of the teaching/learning process. And science, in this case neuroeducation, provides the knowledge for deep learning to take place. How to measure whether this deep learning actually takes place is a question that is beyond the scope of this paper, although it will be taken into consideration for future teaching strategies.

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