Contemporary Engineering Sciences, Vol. 14, 2021, no. 1, 11 - 22
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ces.2021.91619

Didactics and Sustainability. A Different Paradigm in the Search for Other Ideas: Dynamic Architecture

Gastón Sanglier Contreras, Eduardo J. López Fernández, Sonia Cesteros García and Roberto A. González Lezcano

Universidad CEU San Pablo, Escuela Politécnica Superior
Área de Ingeniería de la Construcción, Campus de Montepríncipe
Boadilla del Monte, 28660, Madrid, Spain

Abstract

This paper presents some ideas, methodology and conclusions of the pilot project that has been carried out at the CEU University - San Pablo de Madrid during the academic years 2018/2019 and 2019/2020 where students developed their knowledge of fluid dynamics applied to Architecture, learning methodologies and commitment to sustainable development. The general results are very promising in order to use a didactics of the type indicated in this work in order to favour the number of students that can overcome the subject, as well as to evaluate the commitment with sustainability of the students.

Keywords: Dynamic Architecture, Sustainable Development, Collaborative Learning, Didactics, Higher Education

1. Introduction

Since the beginning of humanity, man
has sought to surpass the limits of previous generations in every respect. The new sequenced limits of Architecture have been written in history to be remembered by the new generations, but those new limits and perspectives have extended to the buildings, now they are able to change their form and be part of the environment mimicking it in some cases (2).

Dynamic architecture, as it is known in the 21st century, involves a different style of construction. The building, or house, is a product whose parts can be prefabricated like any other product. Therefore, new factories and production centers would have to be opened according to the needs of the new architectural and dynamic designs (4,8). After having the architectural plans, the manufacturing of the different parts should be carried out, carefully reviewing each one of them to be taken to the construction or installation site and assembled. Two of the main icons of this type of architecture are the Spanish architect Santiago Calatrava (9) and the Italian David Fisher.

Santiago Calatrava is the author of the project for the expansion of the Milwaukee Museum of Art (9) in 1994, previously granted to the Finnish Eero Saarinen (7) in 1957. He proposed the existence of an independent design that would contrast with the existing volumetry and geometry, being able to attend to changes in texture, form, colors and materials. He designed a pavilion inspired by a boat with the outstanding forms in steel and white concrete. The project had as one of its axes a kinetic structure in steel and glass that resembles a bird about to fly. The structure has the function of a sunshade with the task of regulating the light and temperature inside the building, and moving according to the position of the sun during the day (10,17,23,24).

Skyscrapers suffer the inclemency of the weather, among them they suffer the effects of the wind, but why not use its effects, why not benefit from nature instead of fighting it?

The architect David Fisher (5,10) maximum representative of this type of architecture has devised some dynamic towers in Dubai, Moscow and New York, they are skyscrapers of about eighty floors where each one turns on itself of independent form, the first impression on having seen them is that one is before a tornado where his occupants can change the vision of the landscape at any moment. These towers are the first buildings that turn, move and change shape constantly which gives the idea that it is a different building at all times. The entire structure rests on a central axis to which the floors are attached. Each of its floors can rotate at the speed chosen by the tenant, but what makes this type of building more attractive is that it is presented as the most ecological and energy self-sufficient building since it generates electricity by taking energy from the sun and the wind thanks to a large number of wind turbines arranged horizontally between each floor to which solar panels installed on the roof are attached. It is studied how to mitigate the environmental impact, the use of flexible pipes and the use of solar energy (12).

Dynamic architecture is a concept that tries to show the idea of what contemporary architecture means when taken to any level of design, thus breaking the idea that quality architecture is elitist.

Today, we can say that we are witnessing the birth of "dynamic architecture": the Italian David Fisher designed the so-called "Rotating Towers", rotating skyscrapers where, using prefabricated pieces, each floor of the building can change the orientation of its floor to change the views or follow the path of the sun with a single vocal order from its owner. They are ecological buildings with huge wind turbines in their plants, that is, systems that will allow the production of wind energy.

According to Fisher, each tower could generate energy for a dozen buildings of this type (see figure 1).

Figure 1. David Fisher's dynamic towers. Appreciation of the changing architecture and details

Architecture, since it is a fundamental part of the human being and one of the fine arts, seeks to adapt new ideas and also to make known the new trends that are emerging in the course of this century. It also makes known the world's concern for taking care of the environment by taking measures such as: the use of clean and less polluting energies.

2. Methods and Materials

2.1 Didactics and Sustainability

In today's world, which is constantly changing, education is the pedagogical tool to provide students with the intellectual tools to adapt to the new demands of the working world and the expansion of knowledge.

It’s necessary a different planning and teaching strategies that favor the reflexive learning and a more prepared education to face the new changes, uncertainties and the dynamics of the labor scenario due to:

- The rapid advance of ICT (Information and Communication Technologies).
- The new learning methods based on other principles such as discovery and participation, with the incorporation of new software tools.
- The increase of available information and access to it.
- The new preparation of the teacher, aimed at teaching students to orient themselves towards their own learning.

We have teaching-learning methods that have been recognized by Didactics among which are problem-based learning, project-based learning, the chaos method, discussions, group dynamics and collaborative learning in the classroom among

others. All of them can be combined to favor in the students the development of interpersonal skills and teamwork (19).
The current University also has a great responsibility to guarantee the formation of knowledge, skills and values in the professionals of the future based on ethical, methodological, pedagogical and conceptual principles that guarantee a Sustainable Development.
Faced with the great environmental problems of the moment, it is necessary to provide environmental training aimed at achieving a sustainable development closely related to society, where students will develop their professional and / or scientific work.
The link between Society and the University related to the formation of professionals must be done from the point of view of a principle of change; it cannot be adapted to the processes of the environment but rather improve and transform it from the perspective of Sustainable Development. Professionals must be created who are reflective, critical and sensitive to the changes of the new world, and who are more focused on the processes of creation-production-innovation (13).

2.2 Theoretical Foundations

Within the teaching-learning methods, the methodology of project-based learning has been used to develop this teaching project. This method allows the student to carry out a permanent process of reflection where the teacher leads him/her to face real problems in order to understand and apply the theoretical-practical content learned and developed in class.
With the realization of this project, we have sought that the student puts his ideas into play, discusses them, evaluates them and knows how to evaluate the proposals of his peers always on the basis of a planning of the steps to follow indicated by the teacher. This also highlights the collaborative learning of all students participating in the project.
During the academic years 2017/18, 2018/19 and 2019/20 in the class of the subject of Physical Foundations of Architecture I of the first year of the Architecture Degree of the Escuela Politécnica Superior belonging to the Universidad CEU-San Pablo de Madrid (22), The theoretical part of the class dealt with the subject of Fluid Dynamics and looked for a possible application to modern architecture, carrying out a small project using the concepts seen in class of fluid mechanics, to communicate movement by applying pressure to certain elements of small houses, such as doors, windows, roofs, etc. , oriented to the modern concepts of Dynamic Architecture discussed in class (6,18).
The project is based on the use of Pascal's principle (1), which says that: "An external pressure applied to a confined fluid is transmitted uniformly through the volume of the liquid".
According to this law, if an input force (F1) acts on an area plunger (A1), it will cause an output force (F2) that will act on a second plunger (A2). With this we have that the inlet pressure is equal to the outlet pressure. You can reach the relations:

$$P = F/S; \qquad F_1/A_1 = F_2/A_2$$

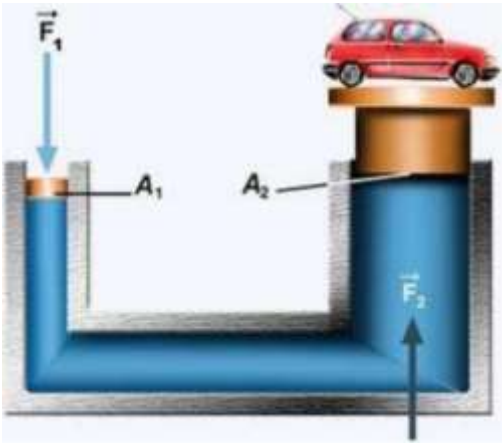

Figure 2. Diagram of the application of Pascal's principle

Because of similarity can be applied to the pairs of syringes and tubes that form the practical application, the long cylinder in the figure can be divided into two individual cylinders of the same diameter and placed at a certain distance from each other connected by a pipe. The same principle of pressure transmission can be applied, and the pressure developed in the smaller piston will be equal to the pressure exerted by the larger piston, as can be seen in figures 2 and 3.

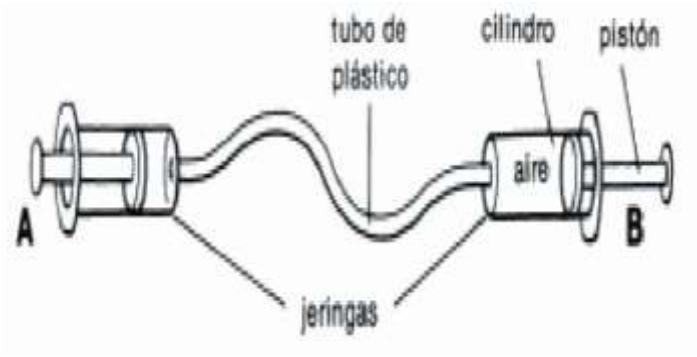

Figure 3. Wiring diagram of a syringe system

2.3 The Project: experimental phase

The main objective of this Project was to try to motivate the first year students in the subject of Physical Foundations of Architecture I by orienting their theoretical foundations, in this case of fluid mechanics, towards Architecture.

To carry out the project, low cost materials were used and, it was tried that they were recyclable, mainly the syringes and the hoses (flexible plastic tubes) to take advantage of the force that these small hydraulic presses provide and thus to give movement to what later will conform the different parts of the building.
Other materials used were: cardboard sheets, glue, paper and papier-mâché. As a fluid, colored water with different colored dyes was used to identify the movement of each system. An attempt was made to reuse all the materials used in practice, taking into account the idea of recycling them.
The reason why three pairs of syringes and the corresponding hoses were used, is because a pressure transmission was needed to make the plungers of the syringes move a certain distance, causing the linear movement of the different parts of the building (walls, windows, doors, etc.) and because of work and time limitations of the project.
Each pair of syringes works as a hydraulic press, having a confined fluid and is transmitted to another syringe applying a force on the plunger, this is transmitted and makes the other plunger move.
To carry out the practice, two models of housing were built, models A (figures 4 and 5) and B (figures 6 and 7).
In both models, it was proposed to build a small model of a building and to provide certain parts of it with movement using syringes and flexible plastic tubes that contained the fluid (colored water) in order to provoke certain movements of partitions, windows and elevator.
Next, in figure 4 there are three images 1, 2 and 3 where different views of the two-storey house called model A made by a group of students can be seen. The house could be a jewelry store in the center of Madrid where it would be interesting to move different modules (rooms) to hide the exposed genre during the night, for example. The safety of the material, in this case, is fundamental.

Figure 4. Different views of model A housing made by students

There are three syringes aligned and mounted outside the house, where each of them controls the displacement of different blocks of the house that can be seen in figure

5. Arrows have been used to indicate the blocks that have been displaced by activating only one syringe.

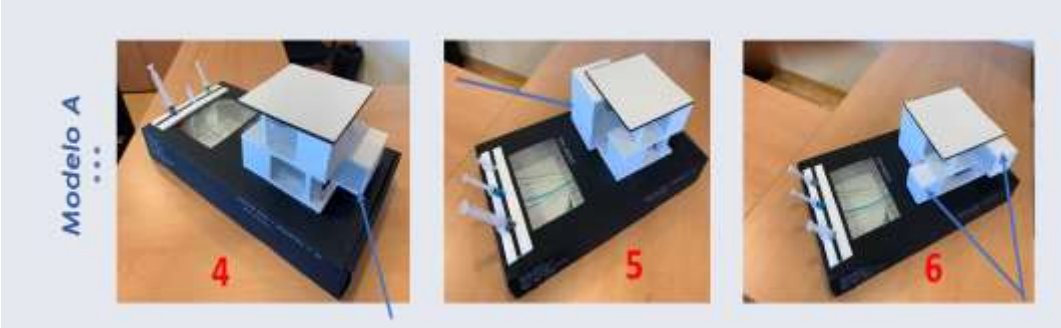

Figure 5. Different displacements of modules in housing model A

Images 4, 5 and 6 in figure 5 show different displacements of the modules of the two-storey model A house.
The movements achieved have been movements on a horizontal plane of different modules/walls in the house changing the shape of the housing envelope, in a similar way to a house in a truck or motorhome where more space is achieved due to the displacement, using hydraulic systems, of removable modules on both sides of the truck, which makes this type of mobile home more habitable.
The model B presents two houses together in one floor, the students represented two workshops of Architecture where the orientation and the light are very important parameters. In this model, the same principles were applied to move different parts of the house by means of the pressure exerted on a fluid to cause a straight movement in those parts.
Figure 6 shows different views of the house of model B where you can appreciate its characteristics in terms of distribution of the modules.

Figure 6. Different views of model B housing made by students

Figure 7. Different displacements of modules in housing model B

In figure 7 and in images 4, 5 and 6 we can see the opening of the entrance door, the vertical displacement of the exterior elevator, and finally, the oblique displacement of the windows on the sloping roof of the workshop, which demonstrates the practical application in three different movements, unlike model A which only did it in one(15).
A comparative study has been carried out of the results obtained in the 2017/2018 academic year without the use of this type of teaching methodology, and the 2018/2019 and 2019/2020 academic years where they have been applied. The following table shows the results obtained according to their grades for the Fluids part of the Physical Foundations of Architecture I course.

COURSE:	**2017/18**		**2018/19**			**2019/20**		
Calification:					Difference			Difference
	Students	%	Students	%	%	Students	%	%
Honorable Matriculation	0	0	0	0	0	1	2,27	2,27
Excellent	0	0	2	5,26	5,26	4	9,09	9,09
Notable	2	12,5	9	23,68	11,18	13	29,55	17,05
Approved	6	37,5	14	36,84	-0,66	14	31,82	-5,68
Suspense	7	43,75	10	26,32	-17,43	8	18,18	-25,57
Not presented	1	6,25	3	7,89	1,64	4	9,09	2,84
Total students:	16		38			44		

Table 1. Comparison of results between courses

As can be seen from table 1, the results obtained in the 2018/19 and 2019/20 academic years using learning methodologies favour the final results obtained from that part of the subject, where these techniques have been introduced. The number of students suspended has been reduced from 43.75% (without application of methodology) to 26.32% (2018/19 school year) and 18.18% (2019/20 school year), that is, in the last school year the number of suspended students has been reduced by 25.57%, a very promising number. This figure is not negligible in this type of subjects where school failure has increased alarmingly.

3. Results

In spite of the difficulty of the subject to study, and in particular the way of thinking, developing and applying the theory, the students showed a high degree of commitment in the different phases of the class-project. This project helped to understand the concepts studied in class and their application to different scientific areas including Architecture.

The students showed a great predisposition to work in groups, the collaborative work was promoted as a platform to contribute and discuss new ideas to carry out their project.

The two projects provided show how fluid theory can be incorporated into the different movements of the various panels and elements of a building to create a different architecture that plays with the movement of its spaces in an accessible, economical and recyclable way (3).

The aim is for students to give a nod to this type of architecture and to do different things with their training and creativity.

The different teaching strategies used in the project have proved valid at a specific time and context. However, the difference in groups, teachers, materials and scenarios forces each teacher to create his or her own strategies and teaching-learning methods (25).

Didactic resources must be elaborated that allow the students to have access to the information they need, what motivates them and almost guides them to develop new abilities, evaluate the acquired knowledge and provide other didactic spaces of expression and development.

We have tried to develop in the students a process of environmentalization and mentalization towards processes of reuse and recycling of materials according to a Sustainable Development closer to the principles of the University.

Increase in the number of approved students in the area where this type of project has been introduced by around 25%.

4. Discussion

Currently, and due to the pandemic situation, where most of the education has gone from being presential to virtual, the application of these technologies that are pro-

posed is more complicated for several reasons, in the classroom the students are more controlled by the teacher and the teacher is more on top of their evolution and sees them live, let's say that contact with the student is very necessary to observe their progress (21).
The realization of the different models in situ, where the students develop their potential, is also different. The live teacher can monitor more closely the construction of the different models, and in cases where necessary, advise new ideas to be developed by the students. The teacher's control is more dynamic and direct over the group.
The introduction of ICTs can create an important gap between the students who are more vulnerable, since they do not have the economic capacity of other more affluent students from other social classes (11).
The effort of the teachers is also important, since they must be up to date with the new technologies that evolve many times faster than their capacity to assimilate them. It must be taken into account that the average age of teachers is usually high and they find it more difficult to adapt than young teachers who are more accustomed to this type of new technology. Often teachers are subjected to a high number of adaptation courses that are not easily assimilated in their working day and must spend many hours to catch up, this coupled with a large number of temporary contracts, causes a great handicap of demotivation of the teacher.

Acknowledgements: To all the students involved in this Project and their teachers for providing them with the tools and knowledge necessary for the development of their projects.

The authors wish to thank CEU San Pablo University Foundation for the funds dedicated to the Project Ref. USP CEU-CP20V12 provided by CEU San Pablo University.

References

[1] A.B. Alturo, *Fundamentos de fluidos y termodinámica*. https://morebooks.de/store/es/book/fundamentos-de-fluidos-y-termodinÃ¡mica/isbn/978-3-659-09421-7 (2015).
[2] T. Anasagasti, Enseñanza de la Arquitectura. Madrid: Instituto Juan de Herrera, (1995).
[3] J. Avellaneda, El concepto de reciclabilidad aplicado a los materiales de construcción y a los edificios: propuesta de índices para evaluar la reciclabilidad de los sistemas constructivos, *Tesis Doctoral*, Barcelona: España. Universidad Politécnica de Catalunya, (2012), 362p.
[4] A. Bahamón, Arquitectura Textil – Transformar el espacio. Sant Adrià de Besòs: Instituto Monsa de Ediciones, (2004), 171.

[5] S. Bayley, *Burj Dubai: The new pinnacle of vanity*. http://www.telegraph.co.uk/news/worldnews/middleeast/dubai/6934603/Burj-Dubai-The-new-pinnacle-of-vanity.html, (2019).
[6] P. Castillo, I. Cobos and C. Molina, El aprendizaje basado en problemas (PBL) en el aula de Humanidades: Trabajo por Proyectos en traducción e interpretación en Historia del Arte, *Revista de Innovación y Buenas Prácticas Docentes*, **7** (2017), 101-124.
[7] L.G. Crespo and I.M. Robles, Del campus industrial al campus tecnológico. Albert Kahn, Mies-Hilberseimer y Eero Saarinen, *Arquitetura Revista,* **12** (1), (2016), 101-124. https://doi.org/10.4013/arq.2016.121.09
[8] P. Echevarría, Portable Architecture. Barcelona: Links International, (2005), 300.
[9] A.E. Escalera, *Santiago calatrava: principios creadores y compilación de su obra (1975-1995)*. https://dialnet.unirioja.es/servlet/tesis?codigo=178428, (2008).
[10] T. Fisher, *The discipline of architecture*, Minneapolis, University of Minnesota press, 2001.
[11] A.C. Grillo, *La arquitectura y la naturaleza compleja: Arquitectura, ciencia y mímesis a finales del siglo XX*. https://dialnet.unirioja.es/servlet/tesis?codigo=6597, (2005).
[12] U.E. Hernández, *La universidad sostenible: nuevos objetivos para la ETSAM*, http://oa.upm.es/51762, (2018).
[13] A. Marcote, Marco teórico y metodológico de educación ambiental e intercultural para un desarrollo sostenible. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias,* **4** (3) (2007), 539-554. https://doi.org/10.25267/rev_eureka_ensen_divulg_cienc.2007.v4.i3.10
[14] R. Kronenburg, *Portable Architecture*, London, Architectural Press, 2003, 274p. https://doi.org/10.4324/9780080523194
[15] Minue, *Casas poco convencionales: una caravana con mucho estilo*. http://hofarc.com/wp-ontent/uploads/2011/03/press_20110317_decoesfera.pdf, (2001).
[16] NAAB - The National Architectural Accrediting Board, Student performance criteria, www.naab.org.
[17] B. Pintos, Arquitectura y diseño flexible: una revisisón para una construcción sostenible, *Tesis Doctoral*, Universidad Politécnica de Cataluña. Editor: Universidad Politécnica de Cataluña, 2019.
[18] L. Portilho and E. María, *Aprendizaje universitario: un enfoque metacognitivo*, http://eprints.ucm.es/4871, (2012).
[19] N.M. Recio and E.F. Ramírez, *Teaching strategies and teaching-learning methods within Higher Education*, 2011, http://scielo.sld.cu/pdf/hmc/v11n3/hmc05311.pdf.
[20] S. Restoy, *Los museos de arte moderno y contemporáneo: historia, programas y desarrollos actuales*, 1999, https://digitum.um.es/xmlui/bitstream/10201/201/1/santiagorestoy.pdf.

[21] G. Sanglier, C.B. Martínez, I. Serrano and J.C. Zuíl, Higher Education in the Face of the Push of New Technologies. Virtual, Augmented and Mixed Reality in the Teaching Environmental. *Contemporary Engineering Sciences*, **13** (1) (2020), 247-261. https://doi.org/10.12988/ces.2020.91601
[22] M.P. Simon, *La evaluación de la calidad de la docencia universitaria. Diseño del modelo de percepción de la satisfacción en la Universidad San Pablo CEU*, 2007. https://dialnet.unirioja.es/servlet/tesis?codigo=171458.
[23] H. Slawik, J. Bergmann, M. Buchmeir and S. Tinney, *Container atlas: A practical guide to container architecture*, Berlin, Gestalten, 2010, 256p.
[24] J.U. Smith, Shipping containers as building elements. California, Department of the Building Environment, (2006), 31.
[25] N. Teymur, *Architectural education, Issues in educational practice and policy*, London, Question press, 1992.

Received: December 14, 2020; Published: January 30, 2021