

WIP: Pre-University Learning Experiences and Their Impact on University STEM Teaching

Dr. David Lopez, Universitat Politècnica de Catalunya

Dr. David López (Barcelona, Spain, 1967). He has a degree and PhD in Computer Science (Universitat Politècnica de Catalunya - UPC, 1991 and 1998). Beyond his technical training, he holds a Postgraduate Degree in East Asian Art and Societies (Universitat Oberta de Catalunya, 2008). His specialties more related to his technical background include computer architecture and structure with special emphasis on storage devices, input/output and organization of Data Processing Centres. His other specialties are engineering education and the relationship of technology with sustainability, ethics and human rights. Since 1991 he has been working as a lecturer in the Department of Computer Architecture at the UPC (Barcelona, Spain), where he has been an associate professor since 2001. He has been a consultant for the Universitat Oberta de Catalunya. His thesis dissertation was about architecture design, optimization and numerical code compilation. Since 2004 he has made engineering education and its relationship with ethics and sustainability his main research topic, with more than one hundred and fifty scientific and press papers published in these years. He has participated in a dozen research projects funded by various entities, including the Spanish government and the European Economic Community.

Mr. Raúl López Sánchez, Universitat Politècnica de Catalunya

Mr. Raúl López Sánchez holds a degree in Computer Engineering (Universitat Oberta de Catalunya, 2010) and a Technical Engineering degree in Management Informatics (Facultat d'Informàtica de Barcelona, Universitat Politècnica de Catalunya, 2002). His professional career has been primarily focused on teaching, particularly in secondary and vocational training education. Since 2019, he has served as an associate lecturer at both the Institute of Education Sciences and the Facultat d'Informàtica de Barcelona of the Universitat Politècnica de Catalunya (UPC). His main area of research is Education in Engineering, Science, and Technology, with several publications in this field.

Dr. Josep Fernandez, Barcelona School of Informatics - Universitat Politècnica de Catalunya-BarcelonaTech

Dr. Josep Fernandez holds a Master's degree in Informatics from the Facultat d'Informàtica de Barcelona and a PhD in Informatics from the Universitat Politècnica de Catalunya (UPC). His academic background includes specialization in computer engineering, perception systems, and robotics.

Following professional experience in both public and private sectors, he joined the Universitat Politècnica de Catalunya in 1989. He currently teaches at the Barcelona School of Informatics at UPC, delivering courses in robotics, embedded systems, and educational research.

He has also held leadership roles within the UPC, having served as Dean of the Facultat d'Informàtica de Barcelona (2017-2025).

WIP: Pre-University Learning Experiences and Their Impact on University STEM Teaching

Abstract – This work-in-progress aims to analyse the educational tools and methodologies used in pre-university education, with the goal of providing university faculty with a clear understanding of the educational background of students in STEM fields. This includes the projects they have been involved in, the resources they have used, and the most effective methodologies. Additionally, this work aims to identify and highlight existing networks within the surrounding educational system (omitted for blind revision). This will allow university instructors to consult and draw inspiration from these networks to enhance their own teaching practices.

Keywords – Active Methodologies, STEM education, educational innovation

I. Introduction

This WIP examines the tools and methodologies used in pre-university education to assess their effectiveness for potential application in higher education. It aims to provide university educators with a clear understanding of the educational profile of students in STEM fields, particularly regarding the use of active learning methodologies. The paper reviews the projects students have participated in, their learning sources, and the most effective methodologies, while highlighting educational networks that could inspire and enhance pedagogical practices at the university level.

In recent years, educational innovation has evolved in response to current demands, promoting methodologies that encourage active student participation and redefining the teacher's role as a facilitator. This paradigm shift moves away from traditional methods focused on memorisation and prioritises skills such as critical thinking and problem-solving.

University professors now face the challenge of adapting their strategies for students who have prior experience with active methodologies. Are these methodologies new to them, or are they already accustomed to them, with no significant advancements? If traditional lecture-based methods are used, do they represent a regression in learning? Furthermore, how do students perceive the methodologies employed at the university?

Among the predominant methodologies in the educational system are project-based learning (PBL), gamification, and service-learning, implemented in primary and secondary education through innovative networks and programmes. As a future line of work, a more in-depth study is proposed with STEM students to examine previous and university-level methodologies, and students' perceptions of motivation when faced with traditional methodologies at university.

II. Context

In our country, education is organised into four stages. Early childhood education (before 6 years) is not compulsory. Primary education, which is mandatory, covers ages 6 to 12, and compulsory secondary education spans from 12 to 16 years old. From age 16, young people can enter the labour market, pursue vocational studies, or continue with the Baccalaureate, a two-year university-oriented.

In primary education, there are no specific subjects for computer science or technology; these contents are integrated into subjects like environmental studies or mathematics. Digital skills and computational thinking are developed, focusing on data organisation, pattern recognition, and creating guided algorithms to model everyday situations.

In secondary education, the subject "Technology and Digitalisation" is taught in at least one of the first three years, covering topics such as programming and robotics. In the fourth year, there is an optional subject called "Digitalisation" [1].

Our work focuses on the pre-university stages, specifically secondary education and Baccalaureate. Although vocational studies are also part of secondary education, the Baccalaureate is more relevant as a pathway to university.

In recent decades, secondary education has undergone significant changes globally to adapt to an ever-evolving environment. A 2018 OECD study showed that 70% of member countries had implemented innovative pedagogical approaches, such as project-based and collaborative learning, in at least 50% of secondary schools [2]. These methodologies have been shown to motivate students and enhance academic performance.

In Finland, 85% of secondary schools use phenomenon-based learning, which integrates subjects around a central theme. According to PISA2018, Finnish students who use this approach have a 15% higher problem-solving ability than those who use traditional methods [3] - [5].

Conversely, Singapore prioritises self-directed learning, with 60% of secondary schools offering programmes that empower students to manage their own learning. The Ministry of Education of Singapore reports that students in these programmes are 20% more likely to achieve better results in mathematics and science [6].

Globally, there is a growing emphasis on personalised learning and technology integration in secondary education. As part of the European Union, we are also adapting to these changes. In 2020, the government included the promotion of STEM subjects, inclusive education, and digital transformation in its educational agenda, aligning with the Sustainable Development Goals [1].

In the 2020-21 academic year, 85% of schools in the country employed active methodologies such as project-based learning (PBL) and cooperative learning, aimed at increasing student participation and developing key skills like thinking and teamwork. Moreover, 60% of schools introduced personalised tutoring in 2022, reducing the school dropout rate from 17.3% in 2019 to

13.3% in 2022. In 2021, 75% of schools had programmes to address diversity, facilitating the inclusion of students with special educational needs [7], [8].

Competency-based learning gained traction, with 68% of schools implementing it in 2022, to prepare students for an ever-changing job market. Continuous assessment also became prominent, with 72% of teachers using this method in 2021 to provide constant feedback and better adapt to students' needs.

These methodologies changes reflect the commitment of schools and teachers to improve education through personalisation, inclusion, and a focus on key competencies essential for addressing 21st-century challenges [9].

At the same time, the curricula of degree programmes in education and master's degrees for teacher training integrate active methodologies as a core element, highlighting the collaborative effort of the government and universities to improve educational quality and prepare teachers.

III. The Adaptation of Active Methodologies in University Education

After introducing the context and current methodologies in secondary education, it is now time to analyse the approaches in university education.

University teaching is defined as the higher-level educational process within institutions focused on the search, acquisition, and construction of scientific knowledge, alongside a continuous critical analysis of this knowledge. Traditionally, professors were the central figures in the learning process, acting as the sole transmitters of knowledge. This created a hierarchical, unidirectional, and purely transmissive classroom dynamic, where students did not actively participate or question the content presented [10].

However, a study by Jasso, García-Prieto, and García-Rojas reveals a growing trend towards the implementation of active methodologies in universities [11]. Despite these advancements, preliminary studies conducted at our faculty show that traditional methodologies still dominate. According to the students surveyed, these methods hinder their understanding of theoretical concepts and limit the connection between theoretical learning and its practical application.

As a result, a possible "regression" in university methodologies is observed. Many students transition from educational environments that prioritise active methodologies to a university setting where two distinct models coexist: project-based learning (PBL), dominant in some areas, and traditional methodologies.

In the faculties of education, active teaching methodologies are actively promoted to prepare future teachers for implementation in their classrooms. However, these methodologies have not been widely adopted in the broader university context.

Finally, it is worth considering: What activities did students engage in during secondary education? What experiences did they have in that educational context?

IV. Examples of Methodologies Used in Pre-University Education

A. *Project-Based Learning*

Several teacher networks share pedagogical resources based on active methodologies. In our geographical area, the government has made available a collection of projects developed in different educational centres, centralized by CESIRE (Centre for Pedagogical Resources for Support in Innovation and Educational Research). The platform includes a search engine that allows filtering by educational levels and subjects.

Below are three notable examples of educational projects:

1) *Project "Exploring Different Biological Processes Using CO₂ and O₂ Sensors"*: This project raises initial research questions such as: a) Exploration of photosynthesis and respiration, b) Comparison between the respiration of animals and plants, c) Factors that increase the respiration rate in seeds, and d) Analysis of alcoholic fermentation and biotechnological processes.

Students must answer these scientific questions using CO₂ and O₂ sensors. They also design experimental procedures and analyse the data, with a focus on interpretation through theoretical models and stoichiometric calculations [12].

2) *Project "Working with Electricity"*: This project focuses on activities related to electricity generation and usage. Some outcomes include: a) Creating a Christmas garland and the electrical installation in a home, and b) Analysis and production of an electrical device.

Industrial and artisanal designs are also worked on as part of the learning process [13].

3) *Project "Making our School Green"*: The aim of this project is for students to plan how to save energy in their school and use renewable energy sources. It focuses on four main areas: a) Water and Electricity saving, b) Heat efficiency and c) Recycling and reuse.

These activities encourage the planning and design of sustainable solutions [14].

B. *Gamification*

1) *Scratch*: For several years, computing has been integrated into primary education using block-based programming languages. These languages allow students to quickly develop engaging programs and create their own games. Scratch is one of the most widely used tools in educational centers, facilitating the transition to more complex programming languages [15].

2) *Advent Code*: Another example of a gamification tool for learning programming is Advent of Code. This resource is based on an Advent calendar with programming challenges of varying levels. The challenges can be solved with any programming language, as the platform evaluates the output generated by the program, not the code itself [16].

C. Service Learning

According to the Center for Promoting Service Learning, service learning is an educational proposal that combines learning and community service in a single project. Participants work on real needs in the environment with the aim of improving it, while learning in the process [17].

It has been implemented at various educational levels, including compulsory secondary education, Baccalaureate, and some university studies. Examples in our fields of study include:

1) *Project "Without Raising Your Hand, a New TV Program"*: Designed for students in the audiovisual subject in Baccalaureate, this project involves creating audiovisual materials for local non-profit organisations. The aim is for students to:

- Learn about their surroundings and the activities of non-profit organisations.
- Develop technical skills in creating multimedia content.

The produced materials are delivered to the organisations, which often lack the resources to produce this type of work [18].

2) *Project "No Entity Without a Website"*: In this project, Baccalaureate students in the "Work in Digital Environments" subject design websites for non-profit organisations. The interested organisations can participate and benefit from these creations, thus contributing to the digital development of the local environment [19].

3) *Project "Pill Dispenser: An App for Medication of Elderly People"*: This project, developed by compulsory secondary education students, involves the design and construction of an electronic box for dispensing medication. The box is controlled through an app installed on the elderly person's mobile device, allowing them to manage their medication automatically [20].

V. Future Lines of Work

To obtain more accurate data, we propose conducting an exploratory qualitative study. This approach does not aim to validate hypotheses, but rather to explore existing educational practices and identify the potential reasons behind their effectiveness.

We plan to organise the study through focus groups will include different student profiles:

- First-year students: Those at the beginning or at the end of their first year degree.
- Final-year students: Advanced students who can provide a comprehensive perspective on their university experience.
- Volunteer students: Participants in an academic mentoring programme for first-year students. These volunteers can offer valuable insights into the difficulties faced by the students they support.

The objective is to compare the methodologies used in secondary education with those employed at the university, and to analyse the evolution of learning throughout the degree programme.

This analysis will provide comparative data that will enhance our understanding of the educational process.

Currently, we are developing an initial phase of the study with a focus group of final-year students. The questions posed are grouped into the following categories:

- Initial perception of the profession: Opinions about the Computer Engineering degree at the beginning of their studies.
- Motivation for choosing the degree: Factors that influenced to enrol in the programme.
- Prior preparation: Assessment of academic background and skills before university.
- Evaluation of teaching methodologies: Critical analysis of the educational strategies employed and their impact on learning.
- Suggestions for improvement: Recommendations for optimising courses and teaching methods to enhance the quality of education.

The information gathered will inform improvements to pedagogical approaches and course structures, leading to a more effective educational model tailored to students' needs.

VI. Acknowledgement

This work has been funded by the Departament de Recerca i Universitats de la Generalitat de Catalunya – 2021 SGR 01412 and by the Universitat Politècnica de Catalunya, Projectes Galaxia d’Aprentatge 2024 – Projecte PROPER-FIB.

REFERENCES

- [1] D. López, F. Llorens Largo, M. Marqués Andrés & J. A. Velázquez-Iturbide. “Proposals for the Promotion of Computing in K-12 Studies in Spain.” in 2023 *IEEE Frontiers in Education Conference*. 2023 doi: <https://doi.org/10.1109/FIE58773.2023.10343195>
- [2] OECD, “Education Policy Outlook 2018: Putting Student Learning at the Centre” in *OECD Publishing*, 2018. doi: <https://doi.org/10.1787/9789264301528-en>.
- [3] OECD, “PISA 2018 Results (Volume I): What Students Know and Can Do”, in PISA, OECD Publishing, 2019. doi: <https://doi.org/10.1787/5f07c754-en>.
- [4] OECD, “PISA 2018 Results (Volume II): Where All Students Can Succeed”, in PISA, OECD Publishing, 2019. doi: <https://doi.org/10.1787/b5fd1b8f-en>.
- [5] OECD, “PISA 2018 Results (Volume III): What School Life Means for Students’ Lives”, in PISA, OECD Publishing, 2019. doi: <https://doi.org/10.1787/acd78851-en>.
- [6] C. Alison, U. Kyoko & N. Hironari. “Student Learning Space: The Integration of Curriculum and Technology in Singapore.” in *ICEMT 2019: Proceedings of the 2019 3rd International Conference on Education and Multimedia Technology*. pp. 37-40, July 22, 2019. doi: <https://doi.org/10.1145/3345120.3345192>.

- [7] A. Escarbajal Frutos & G. Martínez Galera “Use of active methodologies in childhood, primary and secondary educational centers” in *International Journal of New Education*, 2023, no 11, p. 5-25. doi: <https://doi.org/10.24310/IJNE.11.2023.16452>
- [8] Ministerio de Trabajo y Economía Social. Gobierno de España. “INFORME JÓVENES Y MERCADO DE TRABAJO N° 38, 2023 T2”. 2023 [Online] Available: https://www.mites.gob.es/ficheros/ministerio/sec_trabajo/analisis_mercado_trabajo/jovenes/2023/Mercado-laboral-jovenes-Num38-II-Trim-2023.pdf (in Spanish)
- [9] M. Prince. “Does active learning work? A review of the research” in *Journal of Engineering Education*, 93(3):223-231. 2004. doi: <https://doi.org/10.1002/j.2168-9830.2004.tb00809.x>.
- [10] M.J. León Guerrero & Crisol Moya, E. “Questionnaire design (OPPUMAUGR y OPEUMAUGR): The views and perceptions of teachers and students on the use of active methodologies at the university” in *Profesorado. Revista de Currículum y Formación de Profesorado*, 15(2), 271-298. 2011. ISSN: 1138-414X. (in Spanish).
- [11] R. D. Jasso, F. J. García-Prieto & al.. “Active methodologies in the university: international bibliometric analysis (2003-2023)” in *Formación universitaria*, vol. 17, no 4, p. 151-162. 2024. doi: <http://dx.doi.org/10.4067/s0718-50062024000400151> (in Spanish).
- [12] S. Lope & F. Guitart. “Exploramos diferentes procesos biológicos utilizando sensores de CO₂ y CO₂”. *CESIRE–ámbito de ciencias. Servicio de Innovación y Formación de la Educación Secundaria. Departamento de Educación*. 2018. [Online] Available: <https://apliense.xtec.cat/arc/node/30851> (in Catalan) [Accessed February 11, 2025]
- [13] F. M. Ortiz & E. Sanhuja. “ABP i Moodle.” *CESIRE–aulaTEC*. 2011 [Online] Available: <https://apliense.xtec.cat/arc/node/1682> (in Catalan) [Accessed February 11, 2025]
- [14] S. Amorós. “Energy”. *CESIRE–aulaTEC*. 2022. [Online] Available: <https://apliense.xtec.cat/arc/node/29266>. (in Catalan) [Accessed February 11, 2025]
- [15] Scratch Foundation. Scratch. [Online] <https://scratch.mit.edu/>. [Accessed Feb, 11 2025]
- [16] E. Wastl. “*Advent of Code*”. 2015-2024. [Online] Available: <https://adventofcode.com/>. [Accessed Feb, 11 2025]
- [17] Associació Centre Promotor d’Aprentatge servei, “Qué es el aprendizaje servicio.” Available: <https://aprenentatgeservei.cat/>. (in Catalan). [Accessed February 11, 2025]
- [18] C. Altayó “Sense aixecar la mà un nou programa televisiu”. 2008 [Online] Available: https://aprenentatgeservei.cat/wp-content/uploads/experiencies/Experiencia-APS_Sense-aixecar-la-m%C3%A0-un-nou-programa-televisiu_Batxillerat_Participaci%C3%B3-ciudadana-intercanvi-generacional.pdf (in Catalan) [Accessed February 11, 2025]
- [19] J. Sorolla Beltran “Cap entitat sense web” *IES Miquel Biada*. 2008 [Online] Available: https://aprenentatgeservei.cat/wp-content/uploads/experiencies/Experiencia-APS_Cap-entitat-sense-web_Ed-obligatoria_Cooperacio.pdf (in Catalan) [Accessed February, 11 2025]
- [20] A. Carré Veciana. “Dispensador de pastilles. Una App per la medicació de les persones grans.” *INS Forat del Vent*. 2016. Available: <https://aprenentatgeservei.cat/wp-content/uploads/experiencies/Experi%C3%A8ncia-APS.-Dispensador-de-pastilles.pdf> (in Catalan)