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From Theory to Practice with Artificial Intelligence: Experience of Project-based Learning in Higher Education

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Abstract
Competency-based training focuses both on the development of capabilities, skills and knowledge, as well as on education in values, experiences and attitudes that, when integrated, are aimed at the successful performance of the student. In this sense, active methodologies, particularly project-based learning (PBL), provide an opportunity for students to apply and develop skills in real situations and through teamwork, making use of the potential of the application of information and communication technologies (ICT), such as Artificial Intelligence. In this context, the present study aimed to assess the methodology applied in the experience of project-based learning and Artificial Intelligence in the online training of mechanical engineers. The experience was developed in the degree of Mechanical Engineering at two universities (National University of San Agustín de Arequipa, Perú and the Technological University of Havana, Cuba) in two subjects, respectively: Mathematical logical reasoning and Pedagogy and didactics of higher education. The analysis was carried out based on a set of achievement indicators (pass, fail, dropout and withdrawal), and it allowed for a comparative study between 2022 and 2023 that offers valuable results in the online training process of these students. The methodology used, the analysis carried out and the impact obtained constitute a motivating guide for today's higher education.

Keywords: Artificial Intelligence, project-based, learning.

5.1. Introduction

The constant demand for change, updating and readjustment of the educational process in the face of various contexts and social transformations places competency-based training in a requirement that cannot be postponed, assuming this pedagogical model as the search for a process that places the student at the center of their training through metacognitive strategies and active methodologies, which affect comprehensive training and lead the teacher in the management and guidance of learning. In this way, the primacy of teaching through learning and cognitive transmission through training is finally eliminated in face-to-face, hybrid, and completely online environments (Urday & Deroncele, 2022; Bernardo et al., 2023).

Project Based Learning (PBL), with an important presence in the literature, is historically recognized as a model, approach, strategy, alternative and other nomenclatures, but the most used and the thesis that is assumed is to consider it as an active methodology. Furthermore, it is recognized as one of the most currently used in higher education, especially in the training of engineers (Mitxelena-Hoyos et al. 2021).

Among emerging technologies, Artificial Intelligence (AI) has been worked on for more than 15 years in its integration into the educational process, based on its impact on online training, as well as tools and methodological alternatives in other contexts. In this field, Artificial Intelligence (AI) offers numerous potentialities, among which the search, compilation and analysis of information in exponential figures and in increasingly reduced times stands out, which poses great help for updating the educational process (Ocaña-Fernández et al. 2019; Baek & Doleck, 2023).

In addition to this are the valuable options for personalization, individualization and feedback in the teaching-learning process, as well as its countless tools and alternatives for the development of student autonomy and participation in their training and growth process, both personal and professional, in all educational areas and levels (D'Mello et al., 2017; Rapanta et al., 2021).

In this framework, this study aimed to assess the effectiveness of the methodology applied in the Project Based Learning experience and the integration of Artificial Intelligence in the online training of mechanical engineers.

5.2. Project Based Learning (PBL)

Project-Based Learning (PBL) is abundantly discussed in the literature, although in a polysemic and diverse way. In some cases it is conceived as a strategy, method, methodology, theory, approach, activity, task, among other terms. In its study, as a common point, its importance and value prevail in the achievement of the student as the center of the process and in its impact on the formation of a group of competencies and values such as leadership, creativity, communication and collaboration. Likewise, its strong relationship is recognized with approaches and theories such as meaningful, cooperative learning, the flipped classroom, and more currently with the integration of information and communication technologies (ICT) (Ayerbe & Perales, 2020; Cyrulies & Schamne, 2021; Zambrano, Hernández, & Mendoza, 2022).

PBL is defended as an active methodology that promotes meaningful learning, by involving students in real and challenging situations that allow them to develop important skills and competencies for their future in the problem-profession-project relationship. PBL is consolidated as one of the methodologies that directly affects the student as the center of the process, where their self-direction is strengthened through self-directed learning (SDL) skills (Loyens, 2008).

Among the particularities of PBL is its practical approach, which focuses on solving real and meaningful problems for students, provoking high levels of creativity and autonomy. Furthermore, the creation of a tangible final product, which implies not only the mastery of the content, but the development of skills, abilities, values and spaces for group interaction that strengthen communication, collaboration, and critical thinking, among others (Villalobos, 2022).

AI can facilitate advanced analytics and tailor learning experiences to individual student needs, taking PBL methodology to a more advanced and adaptive level in the digital age. The combination of PBL, ICT and AI creates a dynamic and student-centered educational environment, where practical application, autonomy and technology converge to significantly enrich the learning process.

5.3. Artificial Intelligence

The growing impact of Artificial Intelligence (AI) influences the educational process in an accelerated manner and from various sciences, such as Computer Science, Statistics, Psychology, Sociology, and Pedagogy, among others. In this multidisciplinary process, a responsible and pedagogically-based integration is required in the first instance in such a way that it contributes to the strengthening of the training process from its broad potential (Bhargava, 2022; Martínez et al., 2023).

In this incessant but necessary search for resources and alternatives for an educational process where technology and virtuality are considered prevailing, the impact of Artificial Intelligence (AI) has curricular, pedagogical and didactic implications and challenges. In this debate, numerous authors, such as González and Silveira (2022) and Bellomo (2023), highlight its importance for the personalization of the educational process, for support and tutoring, as well as for the prediction and analysis of data and results of the training process. They also underline the growing role of educational approaches, such as smart education and precision education, as well as the emergence of various AI applications and technologies in the field of education, such as learning analytics, intelligent tutoring systems, MOOCs, and virtual teaching-learning (EVEA), all this with important reflections on the necessary basic curricular, pedagogical and didactic conception required by the educational model that is defended.

As AI becomes stronger, at a didactic level, it is more easily integrated into the students' need for more meaningful educational practices, related to their reality and problem solving, as well as facing new challenges that mobilize knowledge, thinking and capabilities, such as values, decision making, feelings and competencies related to leadership, creativity, collaboration and autonomy (Padrón et al., 2022; Álvarez-Álvarez, 2023).

In this order of ideas, important similarities can be observed between the educational demands and the competencies presented with the professional model in the training of engineers, where educational innovation is insisted upon (Rodríguez et al. 2011; Cundulli & Elizabeth, 2023).

5.4. Didactic Proposal Implemented for PBL Through AI in Engineer Training

Various criteria are found in determining the steps or phases and the key questions for the organization and methodological planning of PBL. Among them, they are recognized from 4 phases (choice and motivation, planning, development and evaluation) (Rodríguez & Hernández, n. d.). Other authors describe it in ten steps, such as López, Gómez, & Ramos (2022), which are followed as a reference for the preparation of the proposal. In this case, it is structured systemically, in 8 steps, with a hierarchical and dependency relationship (Figure 5.1).

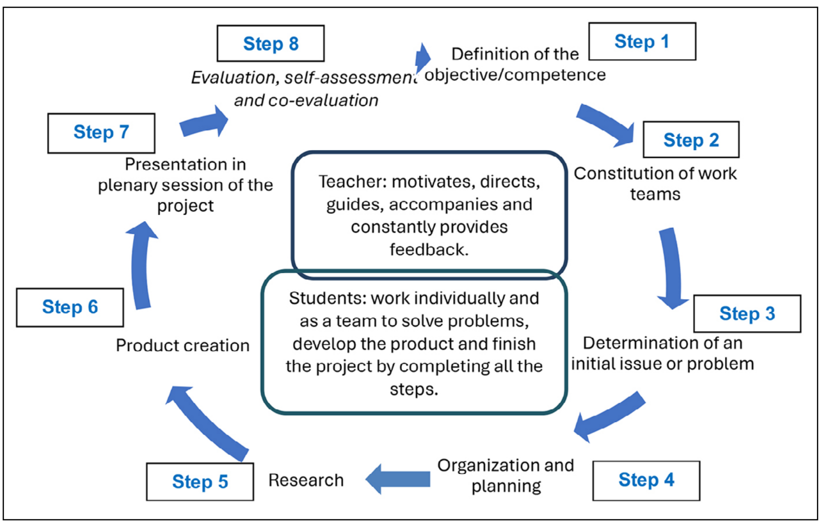

Figure 5.1. Methodological structure for the application of PBL. Source: developed by author.

Methodological guidelines

Step 1. Definition of the objective/competence:

- Identify and develop the objective/competence of the teaching unit. In this case, the integration of several teachers from various careers is suggested to solve the problem from the integration of multidisciplinary teams, thus an integrated work of teachers and subjects that have related topics must be carried out for the development and evaluation of the project.
- Prepare and select numerous resources that enable the student's autonomous study and motivate research on the topic.
- Use learning itineraries, learning routes and/or course maps so that students can select between several tools to study the theory: base document of the subject (Word, PDF), diagrams and infographics (gGnially, Canva, Visme or Animaker), videos prepared by the teacher and links to magazines, and videos selected by the teacher that complement the essence of the subject content.
- Apply techniques for motivation, such as "a picture and a thousand words", "what do I bring and what do I take", among others.

Step 2. Constitution of work teams:

- The teacher determines the essential criteria for forming the teams, including diversity of skills, styles and learning results, technological conditions to avoid the digital divide, particularities of students with SEN and their integration into the team with support.
- Applying techniques for motivation, role distribution and teamwork. Guide and determine by teams the tools and techniques for group collaboration and teacher feedback, synchronously and asynchronously.

Step 3. Determination of an initial issue or problem:

- At this point, the trip to important places related to the professional's field of action is proposed. Application of interviews with teachers and mechanical engineers. The combination of AI with simulation, virtual reality, and augmented reality.

- At the end of this point, each team must identify the problem that they are going to answer with the help and guidance of the teacher. Techniques related to critical or divergent thinking, conflict resolution, environmental changes, among others, can be applied.
- At this time also, the student should be oriented regarding the evaluation, indicators, and levels of achievement; these characteristics and requirements must be evaluated in your presentation.
- Finally, suggest opportunities in this step for students to participate in the planning, execution, and evaluation of the project (instructional co-design and co-creation).

Step 4. Organization and planning: Among the first activities that students must develop in their teams, always with the guidance, accompaniment, and constant feedback of the teacher, are the following: establish your objectives, deadlines, and intermediate and final tasks; distribution of tasks, roles, and responsibilities; identification of necessary resources and collaboration tools; in this step a group of techniques can be used, such as mental maps, the fish diagram (cause/effect), analogical thinking, and list of attributes, among others.

Step 5. Research:

- In this step, it is important that the teacher prepares the student for the research process, offering numerous resources to prepare them for Scientific Research Methodology. Likewise, provide guidance on the tools and resources that the student can use to achieve the expected results.
- Students in their teams must search, collect, process, and manage information. Prepare a theoretical document that bases the product that will be developed to solve the problem. Guidelines should be offered for this part of the work in terms of citations and the standard to be used, structure, format, etc.

Step 6. Product creation:

- The teacher must offer several resources to motivate the students and show articles, tutorial videos, etc., and how to use the tools and create their product with the help of AI, through different diagrams. In this case, as it is for 4th-year mechanical engineering students, the following resources are offered: AI learning platforms (TensorFlow, PyTorch or scikit-learn); Development kits for robotics (Raspberry Pi or Arduino); Simulation tools (AnyLogic or MATLAB Simulink); Computer-aided design (CAD) libraries (Fusion 360 or SolidWorks); Online collaboration platforms (GitHub); Augmented Reality Tools (ARCore or ARKit); Cloud computing services (Google Colab or AWS Sagemaker); Virtual tutoring platforms (DreamBox Learning) or through the implementation of chatbots (Thinkster Math); collaborative project development platforms (Asana or Trello); Virtual Laboratory Simulators (Labster or ChemCollective); Automatic problem generation tools; Personalized course recommendation systems for the analysis of profiles, preferences, activities, resources, etc.; among many others.

- It is important that students be explained and shown how to respect usage licenses and copyrights, and how to create their own.
- Another aspect to note at this point is the importance of presentations during the creation process. These can be done in team tutorials to assess individualities and resolve the difficulties of each team separately. Several group presentation sessions for collaboration and assessment between teams, promoting peer learning and strengthening team motivation, as well as collective guidance on group difficulties, can also be carried out.

Step 7. Presentation in plenary session of the project: in this step, the teacher's motivation is very important, as well as the application of techniques that mobilize group debate to strengthen critical thinking and creative questioning, which are two fundamental goals in this type of methodology.

Step 8. Evaluation, self-assessment and co-evaluation:

- It is necessary that the teacher shares with the students the indicators, which are instruments and forms of evaluation from the beginning of the process in step 1. The teacher must also maintain personalized and team feedback throughout the process, which allows for the expected progress and the defined objectives.

- The variety of instruments ensures that students are not only evaluated by the product itself, but by the values, capabilities and skills developed in each step of the process, such as, for example, level of creativity, commitment, responsibility, presentation and exposition, research, collaboration, and contributions to other groups, among others.
- It is suggested to apply co-evaluation techniques that allow students to evaluate others. To this end, the teacher must take care of biased judgments, which is why they must carefully select the techniques to use.
- Self-evaluation could be implemented. It is also suggested to apply various techniques and alternatives that enable the exposure of the products to other students of the course, other teachers and students of other courses through contests, exhibitions, etc.
- It is important that the teacher motivates the closure of the project towards the search for new problems and situations that allow the restart of the process and application of the methodology.

The application of PBL, according to these steps, ultimately advocates a cyclical approach that allows restarting again and again, as a new problem arises and a project is organized.

5.5. Methods

Participatory Action Research (PAR) methodology

For this case, Participatory Action Research (PAR) is selected, frequently used for educational and social transformation, which, in turn, coincides with cooperative learning and the search for collective solutions for the common good or purpose towards the construction of new knowledge and the training and development of skills. It is also important to highlight the relevance of orientation and constant feedback from the teacher, who participates during the research process as an active observer.

Participants and context

The research is pre-experimental with a qualitative-quantitative approach, in which an analysis of performance indicators was carried out in two Higher Education Institutions: the National University of San Agustín (UNSA) in Arequipa, Peru, and the Technological University of Havana José Antonio Echeverría (Cujae), Cuba. The subjects selected for this study were Mathematical Logical Reasoning and Pedagogy and Didactics of Higher Education, respectively. As a similarity, the proposal was applied simultaneously in the second cohort of 2023, in the degree of Mechanical Engineering, in the 4th year, and in the modality blended through the Moodle platform. The academic results of these two subjects are compared with those obtained in the previous year, in which the proposal was not applied. Six (6) sessions of coordination and methodological teaching work were carried out for planning, organization and subsequent monitoring of implementation between the two teachers involved. Two of these sessions were conducted face-to-face at UNSA and the rest were performed via video-conference through Google Meet.

5.6. Results and discussion

Quantitative analysis

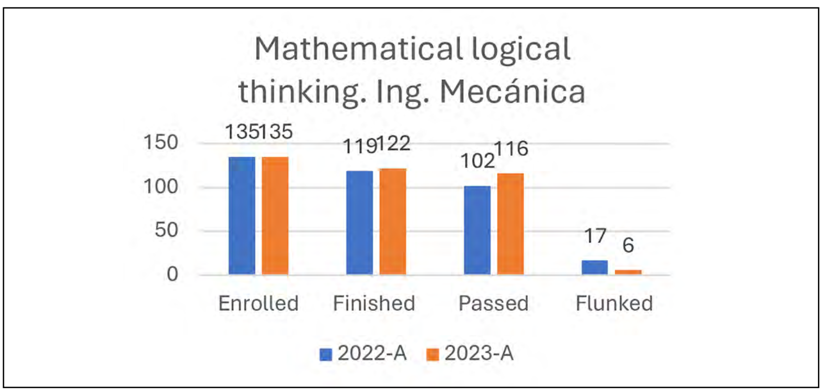

Figure 5.2.A. Results of Mathematical Logical Reasoning subject at UNSA, years 2022 (without application of PBL through AI) and 2023 second cohort (with the application of PBL through AI). Source: developed by author.

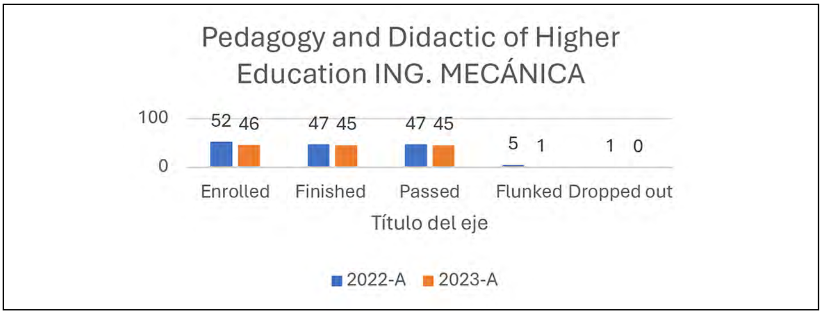

Figure 5.2.B. Results of the Pedagogy and Didactics of Higher Education subject at Cujae, years 2022 (without application of PBL through AI) and 2023 second cohort (with the application of PBL through AI). Source: developed by author.

Qualitative analysis

Students were asked to be part of their own training process, since they participated in the planning, execution and evaluation of the project, following the application of didactic co-design and co-creation (Salido, 2020; Juárez-Pulido, Rasskin-Gutman & Mendo-Lázaro, 2019; Padrón et al., 2022).

Teamwork is essential in PBL, since students must cooperate to achieve the objectives of the project and communicate with each other to share ideas, discuss solutions and make joint decisions, respecting the ideas and opinions of others and demonstrating their own with arguments and evidence (Llorens-Largo et al.,2021; Rua, Henríquez, & Jordán, 2023), all of which is consequently obtained and increases the value of this type of methodology.

The students were involved in solving complex problems that required them to find effective and varied solutions led them to think critically in order to find the best possible solution to a problem and produce the most appropriate product, always with teaching support and collaborative exchange. All this depends on the pedagogical approach that is supported and requires motivation to explore different options. Students were also requested to consider multiple creative solutions, in a motivating and trusting context, so that they could take risks and try new ideas without fear of failure (Llorens-Largo et al., 2021; Albarrán & Díaz, 2021).

PBL through AI contributed to the development of social and emotional skills, which are important for success in personal and professional life to find the timeliest solution, build a product and defend it. In this case, it coincides with the reinforcement of empathy, conflict resolution, leadership, commitment and individual and collective responsibility, which are required in these professions (Batistello & Pereira, 2019; Juárez-Pulido, Rasskin-Gutman, & Mendo-Lázaro, 2019).

Finally, in PBL through AI, the evaluation is not limited to an exam or written test, but rather the entire process of the project and product creation is assessed, from planning to the final presentation and group learning, including aspects of the curriculum in the engineering professional model, such as competencies to achieve in a subject, or generally in several subjects that respond to an area of knowledge, and even respond to interdisciplinary relationships (between several disciplines) and much more integrative competencies (Ye-Lin et al., 2019; García et al., 2020).

It is important to recognize in this experience that the importance of data protection, respect for the authorship of products, content and reused resources was taken into account, which the majority of students value as new learning. Likewise, they recognize the value of teamwork as collaborative and, above all, for the values, feelings and new relationships with students from other fields of study and the opportunities that AI offers throughout the research, production and problem-solving process (Aguilar et al., 2023).

5.7. Conclusions

The didactic proposal offered allows us to see significant advances in the final results of the students in the subjects of Mathematical Logical Reasoning and Pedagogy and Didactics of Higher Education, at UNSA and Cujae, respectively. In addition to the achievements that are evident in these students, it is important to highlight that others also benefit from various careers that are part of the experience and are integrated into the projects on their own initiative.

Despite the challenges currently posed by the integration of AI in the educational process, the obtained achievements show an effective path for its application in higher education. In addition to scientifically proven academic results, an important impact is achieved in strengthening values such as responsibility and solidarity, skills such as creativity and leadership, research skills and feelings of love for the profession. All this significantly increases the value of the proposal that brings, from theory to practice, an experience of project-based learning in higher education using Artificial Intelligence.

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