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NEW BLENDED LEARNING APPROACH TO TEACHING OF ENGINEERING STUDENTS

NUEVO ENFOQUE DE APRENDIZAJE COMBINADO PARA LA ENSEÑANZA DE ESTUDIANTES DE INGENIERÍA

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ABSTRACT:

This article explores the integration of Flipped Learning (FL) and Problem-Based Learning (PBL) as an instructional approach for civil engineering students. The study employed a quantitative, quasi-experimental design involving the deliberate manipulation of independent variables. A total of 227 students were analyzed over the course of one year at three institutions: the University of Ciego de Ávila (UNICA), a public university in Cuba; the Polytechnic Institute of Gaza (ISPG), a higher education institution in Mozambique; and the Catholic University Sedes Sapientiae (UCSS), a private university in Peru. The main findings indicate that the assessment instrument was reliable, valid, and objective. The normality test revealed significant differences between the traditional teaching model and the integrated learning approach, with a p-value < 0.05. Learning satisfaction was reported by 82.52% of students at UCSS, 78.83% at UNICA, and 53.52% at ISPG. The study concludes that combining these pedagogical models fosters engaging education that enhances students' skills and promotes interdisciplinary, lifelong learning.

Keywords: Science learning, Scientific competence, Teaching and learning styles, Learning processes.

RESUMEN:

Este artículo explora la integración del Aprendizaje Invertido (FC) y el Aprendizaje Basado en Problemas (PBL) como enfoque de enseñanza para estudiantes de ingeniería civil. La investigación se aplicó bajo un enfoque cuantitativo, con un diseño cuasiexperimental y una manipulación deliberada de las variables independientes. Se analizó una población de 227 estudiantes durante un período de 1 año en la Universidad pública de Ciego de Ávila (UNICA), Cuba; el Instituto Politécnico de Gaza (ISPG), Mozambique; y la Universidad Católica privada Sedes Sapientiae (UCSS), Perú. Los principales resultados alcanzados fueron que el instrumento resultó ser confiable, válido y objetivo. La prueba de normalidad mostró diferencias significativas entre los modelos tradicional y el aprendizaje combinado con un valor de P < 0.05. Se demostró un estado favorable de satisfacción con el 82.52%, 78.83% y 53.52% de los estudiantes de UCSS, UNICA y ISPG, respectivamente. Se concluyó que la combinación de los modelos pedagógicos proporciona una educación atractiva que mejora las habilidades del estudiante y el aprendizaje interdisciplinario para toda la vida.

Palabras clave: Aprendizaje de las ciencias, Competencia científica, Estilos de enseñanza y aprendizaje, Procesos de aprendizaje

INTRODUCTION

University students must be able to create sustainable solutions for future changes and challenges in social development, as well as anticipate hydrometeorological problems in response to humanity's needs (Sukackė et al., 2022). In particular, hydrology has a high mathematical and statistical content that sometimes causes anxiety, related to epistemological and psychological aspects that lead to rejection of the educational environment (Haag & Megowan-Romanowicz, 2021). This implies a cognitive and affective contradiction regarding teaching and learning (Ramos, 2019) that impacts motivation, creativity, and the establishment of an interesting, engaging, and behavior-oriented ecology, which in turn affects interdisciplinary courses in professional training (Jyun-Chen & Chia-Yu, 2025). Therefore, the relevant professors should practice understanding teaching and learning methods to inspire students to achieve better scientific professional performance with a high degree of integration into innovative practices.

In the United States, higher education has focused on student-centered pedagogy, such as problem-based learning (PBL), which improves student performance in science and mathematics programs (Odell & Pedersen, 2025). PBL is a student-centered learning approach in which students develop a range of competencies in a professional setting (Noguez et al., 2025). PBL-based pedagogy was implemented in engineering starting in 1993, creating a global learning network (Fruchter, 1999). A significant pedagogical method that helps address lecture-heavy engineering courses is the Flipped Learning (FL) model. In this model, according to various authors' definitions, learning takes place through individual instruction at home using virtual classrooms, pre-recorded lectures, videos, audio, and conceptual and theoretical materials, while class time is used for interactive individual and group learning activities (Al Mamun et al., 2022). In fact, class time is maximized through the dynamic resolution of real-world societal problems (Cabi, 2018). In essence, the FL method is a combination of educational principles (Dehghan et al., 2022).

In another context, in the search for new pedagogical models, the two theories FL and PBL, defined as "Blended Learning" or the "Hybrid Model," have been linked, allowing for the combination of digital and face-to-face instruction (Taber, 2018). After COVID-19, the importance of the model for improving learning with a more socio-constructivist pedagogical perspective has become more apparent (Lawshe, 1975). However, in the same vein, the few literary works that address the scope of Hybrid Learning also point out challenges in Higher Education (Menon & Poroor, 2020; Polit et al., 2007; Romero et al., 2023). In this regard, the objective is to propose a new blended learning approach for teaching hydrology to engineering students in Cuba, Peru, and Mozambique.

MATERIALS AND METHODS

Methodology

The blended learning FL-PBL is shown in Figure 1. The process begins with the FL, starting with the student's self-study at home through pre-recorded lectures and consultation materials. Secondly, in the classroom the teacher spends more time to apply learning based on real problems in society. Thirdly, knowledge is expanded based on problem-based learning focused on research projects.

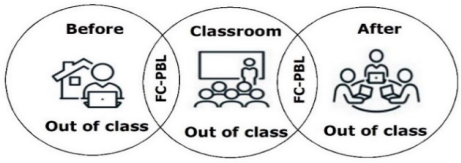

Fig 1: Blended learning.

Improvements in learning are sought through the methodological strengthening of FL-PBL, starting with the collection, explanation and trend of the phenomenon based on the quantitative data matrix (Tomás, 2011). The operationalization of the variables was carried out by considering Flipped Learning (FL) and Problem-Based Learning (PBL) as independent variables, which were intentionally manipulated through the use of digital resources prior to class, active in-class activities, and the resolution of real-world problems in the hydrology course. These strategies were evaluated across dimensions such as resource use, active participation, collaborative work, and critical thinking, using questionnaires, checklists, and rubrics. The dependent variables considered were hydrology competencies and learning improvement, based on cognitive, procedural, and attitudinal performance, as well as academic achievement measured thru objective tests, in order to identify the effect of FL and PBL on the teaching–learning process. A non-probability purposive sampling method was used, selecting students enrolled in the Hydrology course based on their accessibility and relevance to the study. This type of sampling allowed the FL and PBL strategies to be implemented in a real classroom setting.

The instrument applied corresponded to closed answers and a Likert scale. The traditional educational method was applied to the first topic of the hydrology course. The FL-PBL methodology was divided into two phases with a prior analysis of homologation of educational strategies of the universities. The first phase, to establish the students' perception of the proposed method based on generic competencies. Civic Engagement and Social Responsibility

(CESR), Application of Information and Communication Technologies (AICT) and Oral and Written Communication Skills (OWCS). In the second phase, the influence of the FL-PBL methodology on learning. What included the didactic environment, team and individual work, extensive theoretical-practical-technical knowledge, development of creative and critical thinking, application of Information and Communication Technologies (ICT), encouraging research and lifelong learning. The points were evaluated in the teaching sections of classes such as in the lecture classroom, laboratory and development of research projects. The points were evaluated in the teaching sections of classes such as in the lecture classroom (CCS), laboratory (LRS) and development of research projects (DRP).

Methodology development

The methodological development was implemented under the policies of public and private universities from different geographic regions from 2023-I to 2023-II. The public universities belong to Central America, University of Ciego de Ávila (UNICA), Cuba and sub-Saharan Africa, Polytechnic Institute of Gaza (ISPG). Mozambique; while the private one was in the region of South America, private Catholic University Sedes Sapientiae (UCSS), Peru. Six teachers, two collaborators and a student population from 227 participated in the research. The duration of the evaluation was 1 years, equivalent to 2 cycles.

In agreement and quarterly communication, the teachers and collaborators drew up the work guidelines with respect to the student and the topic addressed. In its general format, the class began with reflective discussions, hypothesis statements based on background information, and research on current needs. Attractive and challenging ideas were often formulated to provoke learning in the context of multiple proposals with possible solutions. At the same time, creative and innovative thinking was achieved, generating teamwork, leadership and communication. In other contexts, problems, case studies, research projects and collaborative technical visits to companies were formulated. In summary, it was experienced that the student was the protagonist of his findings on hydrometeorological problems and his systematic learning.

Instrument evaluation

As essential requirements for the evaluation of an instrument, it must have reliability, validity and objectivity (Haag & Megowan-Romanowicz, 2021). The Cronbach's alpha was applied and classified in its hierarchical range 0.5 $<\alpha \leq 0.9$ according to Romero et al. (2023) from excellent to unacceptable. As an element to understand the reliability and validity of the instrument, the Likert Scale was applied. The research was carried out under a margin of error of 2% and probability of 5%. In effect, a sample of students was estimated based on those who completed the hydrology course. The data normality test was applied using the Kolmogorov-Smirnov and Spearman statistical test.

RESULTS AND DISCUSSION

The sample of students surveyed from the population was 217, which generated a percentage of 95.16%, 92.93% and 92.03% at the University of Ciego de Ávila (UNICA), the Catholic University Sedes Sapientiae (UCSS), and the Polytechnic Institute of Gaza (ISPG), respectively. Reliability in a hierarchical range oscillated from 0.768 to 0.874 as shown in Figure 2.

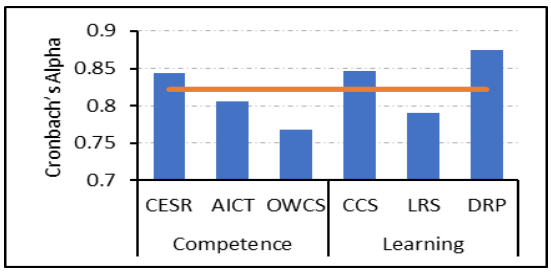

Fig 2: Reliability of the instrument.

As a result, the statistical analysis indicated a non-normal distribution, Pvalue <0.05. But, Spearman's non-parametric test showed that the Pvalue<0.05. Consequently, it is demonstrated that the blended learning of the FL-PBL improved learning performance in universities. Regarding the perception of the students about the blended learning focused on the CESR, AICT and OWCS competencies, the survey showed the existence of a favorable criterion. The students observed an attractive alternative that harmoniously promotes the relationship of the educational, productive and social system. As well as the development of an interdisciplinary learning environment with situations that influence society as a result of hydrometeorological phenomena.

The results of the level of improvement in learning are shown in Figures 3, 4 and 5. There was a notable degree of improvement in student learning at UNICA and UCSS but with respect to ISPG, there was a lower degree of satisfaction in the three spaces evaluated in the lecture classroom, laboratory and development of research projects.

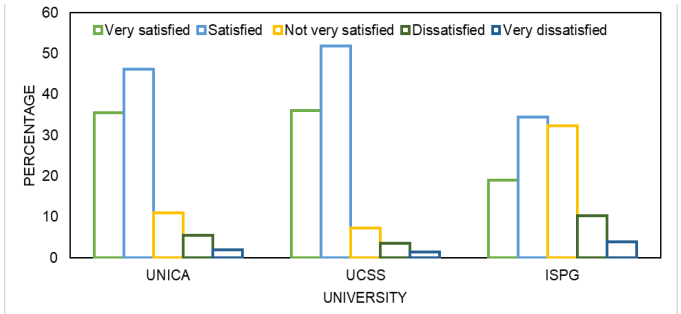

Fig 3: Level in classroom

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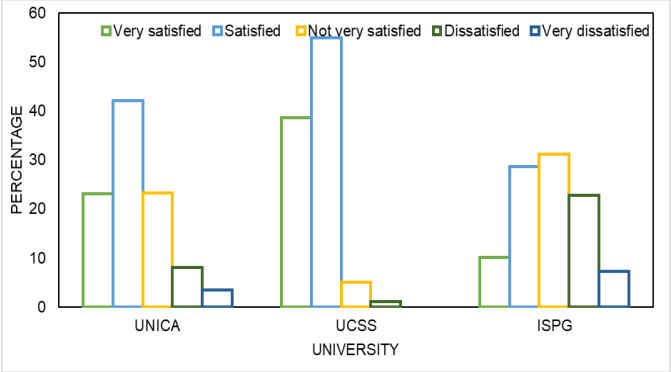

Fig 4: Level in Laboratory

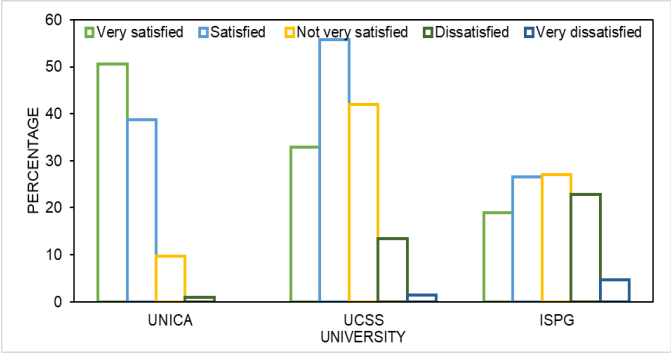

Fig 5: Level in project development

It was demonstrated that the instrument has favorable reliability and validity to obtain the objectivity of the blended learning. Cronbach's alpha as an indicator of reliability reached a hierarchical range between 0.77 and 0.87, classified as excellent to good (Taber, 2018) or a common threshold of acceptability and reliability. The most notable values were found in the development of research projects, and the laboratory indicator was the least significant.

This allows us to ensure, through the surveys, that students appreciated improvements in their learning when using of the FL-PBL pedagogical model for a margin error of 2%. Indicate that teachers also perceived a more attractive methodology to pose new innovation challenges to PBL and development of research projects. Correspondingly, Menon & Poroor (2020) report that, when teachers feel comfortable with class methodologies, students generate quality in their results as a result of the effective increase in knowledge. However, the r of 0.46 at the UM must be analyzed in direct observation, because close to 0.5 is a medium positive correlation, which is indicative of students with little appreciation in differentiating methodologies.

The FL-PBL methodology allowed university students to achieve the Civic Engagement and Social Responsibility, Application of Information and Communication Technologies and Oral and Written Communication Skills. UCSS students showed a better state of satisfaction regarding generic competencies of 82.52% for the Liker scale between very satisfied and satisfied. In particular, the recognition of Civic Engagement and Social Responsibility competence was highlighted. But, compared to the ISPG, it was barely 53.52% for the Likert scale between very satisfied and satisfied. Therefore, about 48% of students were in a state of low satisfaction with the blended learning. The essence of the disagreement begins in the Civic Engagement and Social Responsibility competition, because they lack a computer and mobile devices at home, added to this, the low rate of Internet access that makes it impossible for them to access inverted classes and access to information. In this regard, (Tomás, 2011), point out that, in Mozambique, the inclusion of society in the digital community and in particular university students, is limited by family financial acquisition to invest in technological services and, in turn, the lack of infrastructure with the basic means to study from home. These aspects have an impact on the adaptability and acceptance of new pedagogical models.

Despite the results, there has been a common criterion among students in the methodological effectiveness in improving the competence of oral and written. The skill acquired by students has been a product of their interaction with their student environment and close relationships in their work environment, it will provide an improvement in the ability to make investigative and professional decisions (Naz et al., 2020).

The group of students that achieved the highest degree of learning improvement was UCSS with 87.73%, 93.86% and 88.19% in the lecture classroom, Laboratory and development of research projects sections, respectively. But, compared to the rest of the universities, UCSS is private and does not depend on state funding. In contrast, the ISPG its degree of improvement only reached 53.45%, 38.78% and 45.54 for lecture classroom, Laboratory and development of research projects, respectively. In particular, at the ISPG it was found that there are weaknesses in the conditions for learning. The difficulties begin with the limited use of the university's digital platform as part of the Flipped Learning, that impacts the development of research projects.

In this sense, an impartial response in the blended learning was found in the students through the survey. In turn, it generated little didactic experience in teachers in a multidisciplinary virtual environment (Aguilera & Ortiz-Revilla, 2021). All of this led to weaknesses in the effective implementation of the FL-PBL at the ISPG. Indeed, in the hydrology course at ISPG, 61.25% of students show dissatisfaction. However, recent study (Rhongo & da Piedade 2022) demonstrated higher degrees of dissatisfaction in other educational centers in Mozambique. According several authors Campillo-Ferrer & Miralles-Martínez (2021) and Duan et al. (2021) the limited use of technologies in

universities has an impact on the learning and innovative development of university students.

In particular, UNICA students in the development of research projects section maintained a high satisfaction rate of over 93% for a Likert scale of 4.41. The causes were due to the fact that the Engineering study plans in Cuba included integrative projects in the subjects as part of the strengthening of skills, learning and interdisciplinary research. In addition, the government promotes University-Business relations that allow a broad profile of student knowledge and active motivation in the face of real problems in society.

In general, students showed greater interest in the development of research projects section due to the existence of a practical environment based on the interests and concerns of current and future conditions of hydrology. The approach of the project and problems specific to the region has stimulated the creative and critical thinking of the students based on the PBL pedagogical approach with lifelong learning for the professional. It is shown that generating an environment favorable to knowledge produces a positive effect on learning (Bustamante et al., 2025; Schweder & Raufelder, 2024). UNICA and UCSS students showed more initiative and interest towards PBL innovation and research projects compared to ISPG. Furthermore, the ability to communicate, socialize and exchange with the professors in charge of the hydrology course was more noticeable at UNICA and UCSS.

Differences were observed in the syllable, the ISPG and the UCSS promote the topics of surface hydrology and few topics of underground hydrology. In relation to the UNICA, hydrology is inserted in the subject of applied hydraulics, because in Cuba they train an engineer in the specialty of hydraulics. Therefore, there is a discrepancy in the levels of knowledge of students studying civil engineering in relation to other countries in hydrology. Despite this, there is a trend in the direction of UNICA and UCSS in syllable improvements with a machine learning approach to automate the construction of analytical models (Shen et al., 2021).

It is highlighted that to obtain improvements in the results of the blended learning and its diversification in engineering, the interest of the government, universities, the integration of teachers and virtual debate spaces are required.

CONCLUSIONS

An efficient instrument that has reliability, validity and objectivity was developed to know the effectiveness of the union of the FL-PBL pedagogical models. According to Cronbach's alpha, a reliable material was indicated with a hierarchical range of 0.768 to 0.874. While the validity fluctuated with positive values from 0.14 to 0.72, which classifies as a legitimate instrument with applicability in different geographical conditions, educational diversity, intercultural diversity, development and social cohesion.

Significant differences were demonstrated in the blended learning and the traditional model. In addition, a positive correlation coefficient was reflected through the surveys where students observed improvements in their learning when using the blended learning with a margin of error of 2%. However, teachers perceived a more attractive and friendly teaching and learning method to face the challenges and innovation of hydrology.

There was a favorable state of satisfaction related to the generic competencies acquired by university students. The UCSS, UNICA and ISPG reached a satisfaction level of 82.52%, 78.83% and 53.52% between very satisfied and satisfied for the Likert scale, respectively. While the learning of hydrology in the students generated an emotional state and global interest in the sections of the lecture hall, laboratory and development of research projects of 74.32%, 65.90% and 74.05%, respectively. It was evident that universities with low student satisfaction rates were the product of poor technological, structural and educational policy levels of the government.

As a finding, it was proven that the alternative pedagogical model generates a wide range of skills to enhance, such as information processing, critical thinking, autonomy, teamwork and leadership, which promotes effective communication to face the world of work with a full sense of ethical responsibility, socioeconomic and environmental aspects. The blended learning model is a new way of continuous learning of self-assessment and transmission of interdisciplinary knowledge within hydrological science.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

Authors' Contribution (CRediT Taxonomy)

Author	Roles
Author 1	Conceptualization, Investigation, Methodology, Funding acquisition, Project administration, Resources, Writing – original draft.
Author 2	Data curation, Formal analysis, Software, Investigation, Methodology, Funding acquisition, Writing – review & editing.
Author 3	Investigation, Methodology, Funding acquisition
Author 4	Investigation, Methodology, Funding acquisition