AUDIOVISUAL METHODOLOGY FOR ENGINEERING EDUCATION IN CUBA, PERU AND MOZAMBIQUE

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KEYWORDS
STEAM education
Learning process
Scientific competence
Science learning
Science teaching
Generic skills

ABSTRACT
In this article, the methodological integration of the flipped classroom (FC) and problem-based learning (PBL) in the teaching of the hydrology course was developed. The research is applied with a quantitative, quasi-experimental approach. It was applied to a sample of 1846 Civil Engineering students over 10 years at universities in Cuba (UC), Peru (UP) and Mozambique (UM). The results showed that the best student satisfaction occurred at UP with 89.92%. It is concluded that the fusion of FC and PBL promotes lifelong learning that includes general and specific competencies.

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1. Introduction

Professionals need occupational and professional competencies to achieve sustainable development. In this context, it is a challenge to adapt teaching and learning processes to current times. The curriculum is the main instrument of education systems for translating specific content, competencies and skills into content. However, regardless of the approach education systems adopt to design their curricula, there is not always a direct correspondence between the curriculum and actual teaching and learning in the classroom (Berganza et al., 2022). The 21st century skills are a set of foundational and transversal skills that include digital skills; advanced cognitive skills; executive skills; and socioemotional skills (Mateo et al., 2019). In this regard, Universities in Sweden only employ professors with competencies and pedagogy in the disciplines to be taught, which create the conditions to improve the quality of teaching (Ryegård et al., 2010).

In some countries in the Latin American region, the idea of 21st century skills as a central axis of curricular programs has been well received, but unlike the countries of Argentina, Uruguay, Paraguay and Peru there has been a rejection (Berganza et al., 2022). Various universities have undertaken curricular changes to contribute to the achievement of more equitable learning system through multiple pedagogical approaches (Lozano et al., 2017) which are difficult to cover all sustainability skills (Corvers et al., 2016). Although, k-12 and higher education in the United States of America (USA) in recent decades has focused on student-centered pedagogy as a constructivist teaching method and problem-based learning (PBL). The basis of the educational method stems from research in medical education in the USA (Bruner, 1959) but, there have been diverse empirical results in various branches of science because it covers various sustainable competencies (Beers, 2005, Bloom & Kowalske, 2016, Thomas, 2019, Carrió & Llerena 2023).

Problem-based learning (PBL) is an innovative educational proposal because learning is centered on the student, who manages to develop a series of skills and competencies that are indispensable in today’s professional environment, which has an impact on interest and motivation (Gorghi et al., 2015). PBL poses as a basis, that the problem drives learning, defined as complex tasks that are based on real challenging problems that involve students in the design, diction taking, resolution and research actions (Bridges & Hallinger, 1997). The pedagogy based on PBL was implemented in engineering curricula since 1993, generating a global learning network of more than 20 universities in Europe, Asia and USA (Fruchter, 1999) that has been incorporated over time by other universities in Germany, Holland and other countries (De Graaff & Kolmos, 2007).

Likewise, the flipped classroom (FC) is a new strategy in higher education, modifying the traditional method with a 180° turn. With the application of FC, teachings, theories, concepts and research are transferred to home study as a process aimed at self-monitoring and self-evaluation. Therefore, more time is devoted to dynamic problem solving in the classroom (Cabi, 2018). The flipped classroom seems to be appropriate for engineering education due to a combination of educational principles (Karabulut et al., 2018, Dehghan et al., 2022). Regarding FC and PBL methodology the literature reports successful results in architectural and engineering study plans in case studies from USA, China and Spain (Zhang et al., 2018, Zamora et al., 2019). However, it faces a challenge because it implies a greater knowledge of tools and technologies to perform the activities.

In Cuba, there is little research on FC and PBL in higher education, mostly focused on the study plan of the Medical Career (Varela et al., 2021). The fundamental causes are due to the scarce progress in digitalization, which has an impact on technology compared to other developing countries (Maloney, 2021). Although, the Ministry of Higher Education of Cuba has proposed strategies such as the Integrating Projects that allow the strengthening of competencies in engineering careers. The method promotes interdisciplinarity and involves scientific and technological research in the solution of social, economic and environmental problems (Rivero et al., 2017, Artola et al., 2019, Zúñiga, et al., 2021).

In comparison, in the Peruvian Higher Education, there is scientific evidence of the application of PBL and FC. Del Savio (2023), cited that, with the implementation of PBL in Virtual Design and Construction course of civil engineering at the University of Lima, showed that, students improved by 6.13%, 7.15% and 3.44% of the development of competencies, the degree of learning and project treatment. The FC in Peru has been implemented for decades (MINEDU, 2022), in this regard Alarcón & Alarcón (2021) points out that the effectiveness in deeper and lasting learning over time, with a mean difference of...
6.894 and with a Sig. level (bilateral) of 0.000 with respect to the traditional model. Vásquez et al. (2023) detected that, in the application of the FC in a sample of 75 students of the Universidad César Vallejo in Peru, more than 70% achieved a passing evaluation, which allows the methodology to raise the level of learning in the curricular experience.

Peru is evaluated every 3 years in its competencies by PISA (Programme for International Student Assessment) to estimate the degree of school learning. However, Turpo (2016) states that the quality of education in Peru does not meet international quality standards due to its wide dispersion in educational results.

In the context of Mozambique, higher education makes attempts for the implementation of pedagogical innovations such as migration from conventional classrooms to digital classrooms, flipped classroom (FC), problem-based learning (PBL), considering that the population presents basic, social, economic and regulatory difficulties by the government. Rhongo and Piedade (2022) demonstrated, from a questionnaire conducted to 164 teachers in 15 Higher Education Institutions in Mozambique, that there are basic obstacles such as technological resources and internet connectivity, which only 83% use the digital classroom to manage and deliver online content. On the other hand, Campira et al. (2021) highlights the importance of infrastructure and socio-cultural diversification that hinders the appropriate conditions for the application of pedagogical approaches in teaching and learning of university students. In particular, Mendonça (2014) states that in the process of fostering the process of pedagogical innovations with student-centered learning approach at Eduardo Mondlane University, he detects inadequate access to educational resources, excess of students in the classroom, poor infrastructure and poor creation of didactic materials. However, there are favorable attitudes among professors and students in the new reform. As a result, the various scenarios of the engineer should be strengthened, as well as the integration of didactic strategies.

STEAM (Science, Technology, Engineering, Arts and Mathematics) education is an interdisciplinary reference model that helps students acquire and apply knowledge from diverse perspectives to obtain practical solutions to complex problems (Jesionkowska et al., 2020, Aguilera and Ortiz, 2021).

From an innovative perspective, the STEAM approach not only contributes to teaching scientific concepts, but also makes students more comfortable analyzing, thinking, reasoning, and working with art and science to become creative and innovative thinkers (Liliawati et al., 2018).

STEAM education is problem solving based on definitions and procedures from the sciences, integrating applied strategies in engineering and the use of technologies, art and music (Jesionkowska et al., 2020). The STEAM model is a form of learning based on problem solving, asking questions and seeking new answers, which presents a challenge on how to deliver learning.

STEAM is about developing students' skills in research, critical thinking, creativity, communication and collaboration. But how do we develop the skills and what method will be the most effective? That is why there are universities in the United States, the European Union, Asia and the Middle East that promote active classroom or flipped classroom strategies (Magaña et al., 2020, Coulter and Lindsay 2022).

FC and PBL are known methods, little has been implemented in courses; however, during the COVID-19 pandemic, several universities saw the need to take alternatives for educational development. Therefore, several pedagogical techniques were applied, including FC and PBL, which motivated the writing of several manuscripts, but unfortunately in a short period of time and each technique was analyzed in isolation (Campillo and Miralles, 2021, Eichler, 2022, Yu et al., 2023).

However, if an investigative didactic model based on PBL and FC is inserted in these activities, it should have a positive impact on the learning of hydrology students. In this regard, different authors emphasize that its implementation in engineering requires, in the first instance, the interest of the government and private institutions and, secondly, the integration of teachers from the basic sciences and, finally, there are still some practical gaps for its development (Rogers and Morgan, 1998, Johnson, 1999, Mills & Treagust, 2003).

Therefore, in order to implement these teaching and learning models, the foundations must be laid from a scientific point of view. This pedagogical model based on FC and PBL strategies strengthens not only the interdisciplinary method, but is also a novel and comprehensive tool for teaching and learning in today's world. In summary, the purpose of the study is to propose FC and PBL for teaching and learning the subject of hydrology.
2. Materials and Methods

The subject of hydrology is part of the curriculum of civil engineering students at the international level, as in other earth sciences. In terms of training a professional to solve the problems demanded by society and employers, more captivating scientific criteria achievable and measurable over time were proposed, as shown in Figure 1. The implementation was in the pedagogical methods of FC and PBL, were used as pillars of STEAM (Science, Technology, Engineering, Arts and Mathematics) education.

![Figure 1. Factors of pedagogical integration](Source: Own elaboration)

The research by its type, purpose and objectives meets methodological conditions of an applied research, because it aims to improve teaching through the methodological application of FC and PBL, which generates motivation and knowledge development in the student and the teacher. A quantitative approach was applied to collect, describe, process, explain and predict phenomena in the quantitative database (Hernández et al., 2014). In addition, it uses a quasi-experimental design product to the deliberate manipulation of the independent variables (FC and PBL) to observe the effect on the dependent variables (generic skills, teaching improvement, laboratory and project development and research) as shown in Figure 2.

![Figure 2. Relationship between variables](Source: Own elaboration)

The application of the methodology (FC and PBL) was for all university students of civil engineering, enrolled in the Hydrology course, which indicates that there was no selection or random assignment. In order to understand the phenomenon under a case study sufficient to the context and needs, as well as
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to elaborate a report applicable to a wider population for decision making. Therefore, three experimental groups UC, UP and UM have been generated, corresponding to one university for each country, Cuba, Peru and Mozambique respectively.

Based on previous scientific experiences of the application of the methods, current educational processes should include technological tools to improve the competencies and learning of students. Stanford University developed the methodology called P5BL, which considers five aspects and relates them to Information Technology (IT) (Fruchter, 1997). In particular, the research emphasized the first three, the problem, the project, and the product as the objective to visualize, collaborate, and motivate new knowledge respectively.

The data collection instrument was a digital survey to explore the students’ perceptions of the effect of the FC and PBL methodology in the process of developing generic competencies and learning experiences. The instrument applied for each variable of studies and scenarios corresponded to closed responses based on a Likert scale with five levels. It should be noted that the first subject of the hydrology course was applied the traditional educational method to all enrolled students to verify the degree of acceptance and effectiveness of the FC and PBL criteria.

The first stage of the survey was aimed at the students’ perception of the traditional methodology and the criteria applied, with emphasis on the generic competencies achieved. According to their content, they were grouped into 4 groups: competencies related to learning (CRA), interpersonal relations and group work (RITG), autonomy and personal development (ADP) and, finally, competencies related to values (CRV), which in general respond to the dependent variable. In the second stage, the survey covered the students’ perception of the FC and PBL criteria according to the degree of improvement in the classroom, in the laboratory and in the development of the project/field practicum. The items analyzed in each of the scenarios are shown in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Classroom</th>
<th>No</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Didactic environment</td>
<td>9</td>
<td>Organize information</td>
</tr>
<tr>
<td>2</td>
<td>Promotes participation</td>
<td>10</td>
<td>Processes information</td>
</tr>
<tr>
<td>3</td>
<td>Personalized and group attention</td>
<td>11</td>
<td>Uses software</td>
</tr>
<tr>
<td>4</td>
<td>Provides bibliographic material</td>
<td>12</td>
<td>Extends Hydroinformatics</td>
</tr>
<tr>
<td>5</td>
<td>Feedback</td>
<td>13</td>
<td>Team and individual work</td>
</tr>
<tr>
<td>6</td>
<td>Promotes research</td>
<td>14</td>
<td>Demonstrates reasoning</td>
</tr>
<tr>
<td>7</td>
<td>Visualize the results</td>
<td>15</td>
<td>Interacts with subject matter specialists in the social sphere</td>
</tr>
<tr>
<td>8</td>
<td>Interpret and explain the results</td>
<td>16</td>
<td>Acquires mathematical skills - statistics</td>
</tr>
<tr>
<td>17</td>
<td>Research projects</td>
<td>21</td>
<td>Development of creative and critical thinking</td>
</tr>
<tr>
<td>18</td>
<td>Applies data collection techniques</td>
<td>22</td>
<td>Incorporates ethical values in research</td>
</tr>
<tr>
<td>19</td>
<td>Identifies the appropriate statistical process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Visibilizes possible solutions to real problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Extends theoretical-practical-technical knowledge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Own elaboration

The integration of the FC and PBL methodology was applied to students from public and private universities, which, on the one hand, UC and UM were public and UP was private. The study time has had a duration of 10 years, equivalent to 20 cycles with the participation of 6 professors, 2 collaborators and 1986. The general analysis of the hydrology career was developed in the spaces of communication with the students, such as classroom, practical classes, laboratory, research project and field work. The teacher used didactic media, FC, PBL and research projects as part of STEAM education to facilitate the teaching and learning processes. STEAM in the hydrology course involved all theoretical, practical and research activities to achieve all the skills described in Figure 1.
In the research, the evaluation of the instrument and data collection was carried out based on meeting the three essential requirements; reliability, validity and objectivity (Hernández et al., 2014). For this purpose, the Content Validity Index (CVI) proposed by Laswshe (1975) was applied. The group of students per cycle is considered the main variable by the evaluators. The CVI is calculated using the following equation 1:

$$\text{CVI} = \frac{n_e - N}{N/2}$$  \hspace{1cm} (1)

Where ne is the number of selected students who give the item a rating of essential, N the total number of students who evaluate the content. Laswshe (1975) suggested that the CVI ranges from $+1$ to -1, and positive scores indicate better content validity.

Likewise, the survey was analyzed by the spaces of communication with the students. The "Likert Scale" (Likert, 1932), one of the best known psychometric techniques for its ease of application and accuracy, was used. The Likert scale ranged from 1 to 5, with 1 being very dissatisfied, 2 dissatisfied, 3 not satisfied, 4 satisfied and 5 very satisfied.

As for, the reliability of the applied instrument Cronbach's alpha was raised with a hierarchical range, excellent of $0.8<\alpha \leq 0.9$; good of $0.7<\alpha \leq 0.8$; acceptable of $0.6 < \alpha \leq 0.7$; poor of $0.5 < \alpha \leq 0.6$; unacceptable $0.5 < \alpha$ (Taber, 2018). The sample size was set with a margin of error of 2% at 95% confidence level and 5% probability; which, in turn, corresponds to almost all students who managed to finish the hydrology course.

For the behavior of the data, the Kolmogorov-Smirnov test was applied as a valid test to contrast the normality of the information series with the IBM SPSS Statistics program.

### 3. Results

From the year 2011-I to 2020-II in the universities of Cuba (UC), Peru (UP) and Mozambique (UM) registered 475, 708 and 803 students who completed the hydrology course respectively. These students represented the population for each educational center. Based on the 2% margin of error, 95% confidence level and 5% probability, a sample of 452, 658 and 739 students was reached in UC, UP and UM respectively, for a total of 1846.

The results of the reliability analysis of the instrument applied based on Cronbach's alpha are shown in Table 2. In general, Cronbach’s alpha for each dependent variable and its parameters indicates that the survey is reliable with a hierarchical range between 0.7 and 0.8.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameters</th>
<th>Cronbach's alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competencies</td>
<td>Related to learning</td>
<td>0.844</td>
</tr>
<tr>
<td></td>
<td>interpersonal relations and group work</td>
<td>0.806</td>
</tr>
<tr>
<td></td>
<td>Autonomy and personal development</td>
<td>0.856</td>
</tr>
<tr>
<td></td>
<td>Related to values</td>
<td>0.768</td>
</tr>
<tr>
<td>Learning</td>
<td>Degree of improvement in the classroom</td>
<td>0.846</td>
</tr>
<tr>
<td></td>
<td>Degree of improvement in the Laboratory</td>
<td>0.791</td>
</tr>
<tr>
<td></td>
<td>Degree of improvement in project development</td>
<td>0.874</td>
</tr>
</tbody>
</table>

**Source**: Own elaboration

Table 3 shows the results of the normality tests. The Kolmogorov-Smirnov statistical test indicates a non-normal distribution at $P_{value}<0.05$. Therefore, the Spearman nonparametric test was applied, which showed a correlation coefficient that ranged from 0.23 to 0.46 and a significance level of 0.000 less than 0.05.
Table 3. Normality tests

<table>
<thead>
<tr>
<th>Method</th>
<th>University</th>
<th>Kolmogorov-Smirnov</th>
<th>Spearman test</th>
<th>Source: Own elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>UC</td>
<td>0.457</td>
<td>0.000</td>
<td>0.23 0.000</td>
</tr>
<tr>
<td>FC-PBL</td>
<td>UC</td>
<td>0.457</td>
<td>0.000</td>
<td>0.25 0.000</td>
</tr>
<tr>
<td>Traditional</td>
<td>UP</td>
<td>0.448</td>
<td>0.000</td>
<td>0.46 0.000</td>
</tr>
<tr>
<td>FC-PBL</td>
<td>UP</td>
<td>0.448</td>
<td>0.000</td>
<td>0.46 0.000</td>
</tr>
<tr>
<td>Traditional</td>
<td>UM</td>
<td>0.413</td>
<td>0.000</td>
<td>0.46 0.000</td>
</tr>
<tr>
<td>FC-PBL</td>
<td>UM</td>
<td>0.413</td>
<td>0.000</td>
<td>0.46 0.000</td>
</tr>
</tbody>
</table>

With respect to the Content Validity Index (CVI), it showed a degree of acceptance of the methodological integration compared to the traditional method. The CVI values ranged from 0.14 to 0.72 in positive ascent.

The results of the survey for an error of 2% according to the students' perceptions of the influence of FC and PBL on the development of generic competencies are shown in Figure 3, 4 and 5. In general, students think that applying the FC and PBL methodology contributed to the development of generic skills compared to the traditional method. Also, that students perceived an advantage for their future career. Although, at the University of Mozambique (UM) there is a significant percentage of students who are not very satisfied with the instrument.

Figure 3. Perception of UC students.

[Chart showing perception of UC students]

Figure 4. Perception of UP students.

[Chart showing perception of UP students]
The evaluation of the effectiveness of the FC-ABP was implemented from the scenario of working with the student as a theoretical space in the classroom, laboratory classroom and research project/field practice classroom, as shown in Figures 6, 7 and 8. In general, it is observed that there is an adequate degree of improvement in student learning in UP and UC regarding the three areas evaluated, but in comparison with UM the results are more notable in being dissatisfied with the implementation of the tool, particularly in the computer laboratory space.
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**Figure 6.** Degree of improvement in the classroom

![Bar chart showing degree of improvement in the classroom.](image)

**Source:** Own elaboration

**Figure 7.** Degree of improvement in the Laboratory

![Bar chart showing degree of improvement in the Laboratory.](image)

**Source:** Own elaboration

**Figure 8.** Degree of improvement in project development

![Bar chart showing degree of improvement in project development.](image)

**Source:** Own elaboration

Figure 9 shows the tendency to improve student learning and evaluation systems. A best fit exponential function with a positive integer exponent and a coefficient of determination greater than 0.7 is obtained in the three universities, classified as acceptable.
4. Discussion

The instrument applied according to the Cronbach’s alpha analysis resulted to be in a common acceptability and reliability threshold. Based on the hierarchical range posed by several authors between 0.7 and 0.8, it is classified as excellent, good or adequate (Taber, 2018). Therefore, the questionnaire intended to measure the dependent variables in the different scenarios turned out to be a novel tool because it allowed measuring the students’ motivation towards learning product of the methodological integration of FC and PBL.

The comparison of the FC and PBL methodology with respect to traditional teaching showed significant differences in the three universities (UC, UP and UM). The results of the Kolmogorov-Smirnov and Spearman normality test indicated that the alternative hypothesis (H1) is accepted and the null hypothesis (Ho) is rejected. On the one hand, it is statistically demonstrated that the integration of FC and PBL methods influences students’ learning in the hydrology course in the three universities. The correlation coefficient of Spearman’s test in UC and UP was 0.23 and 0.25 respectively, which according to Hernandez (2014), is a weak positive correlation. It is for this reason that, students reflected methodological differences in the learning system. However, regarding the correlation coefficient in the UM was 0.46 closer to 0.5, which classifies as a medium positive correlation. Therefore, it is deduced that there is a low appreciation in students in differentiating methodologies and their impact on learning, whose causes could be diverse as those exposed by Mendonça (2014) and Campira et al. (2021).

The Content Validity Index (CVI) from the students’ perspective reflected positive values, which are within the acceptable values of 0.14 to 0.72 (Polit et al., 2007), indicating that students approve of the new FC and PBL methodology in the three universities. But according to Tristan (2008), they are more effective when they exceed the value of 0.58. In this sense, 35% of the CVI results would not comply, given the first years of implementation of the methodology. Thus, it can be observed that the dimension of knowledge and learning with the methodology was not sufficiently valued by the students according to Laswshe’s model (1975). However, the results of the CVI as of 2014 II have remained above 0.58, indicating that there is validity of an instrument by the representation of the degree of coherence between the theory that supports the instrument itself and the empirical evidence obtained in its application in students.

The generic competencies grouped into 4 groups and analyzed for each university. The survey showed that UC and UP students are aware of having achieved better generic competencies from the integration of the FC-PBL methodology compared to the traditional one. The results of UC and UP are close to 82% of very satisfied and satisfied, which, in comparison with UM, reaches only 53.05% of students. Competencies related to learning (CRA) and, autonomy and personal development (ADP) are the most influential in UC with 55.53% and 56.54% respectively. While, at UP, the competencies related to learning (CRA) and the competencies related to values (CRV) were the most influential with 47.42%
and 49.09%. On the other hand, in the UM the competencies related to learning (CRA), and interpersonal relations and group work (RITG) with 42.90% and 41.81%.

As a common factor, the CRA competency has been achieved. In particular, CRA is the highest priority competency for university centers, because it is where knowledge about the area of study, the profession, the ability to apply knowledge in practice; identify problems and solve, as well as research capacity are highlighted (Berganza et al., 2022). In the same context, it is highlighted that generic competencies are necessary in civil engineering graduates as an essential element required by the labor industry for problem solving, creativity and teamwork (Del Savio et al., 2023). However, the results of the present study show that UM students have low pursuit of FC and PBL methodology to contribute to the development of these competencies. 48.24% are in a state of low satisfaction.

The influence of FC and PBL in teaching hydrology to engineering students has been analyzed in three perspectives where the student develops skills. UP as a private institution stood out in its standards of degree of improvement in classroom, laboratory and project development with 87.73%, 93.86% and 88.19% respectively, for a Likert scale between 3.71 to 4.17. In contrast, UM as a public institution its degree of improvement in classroom, laboratory and project development with only 53.86, 38.75 and 45.81% respectively, for a Likert scale between 3.11 to 3.55.

In particular, at UM, it was noted that the conditions for learning were weakened, as the computer laboratories exceeded the capacity of students, with up to 3 students per computer. In other instances, internet access is weak with a speed of only 6.1 Mbit/second, making it difficult for students to learn. Consequently, they do not effectively achieve FC and PBL in obtaining and processing information from hydroinformatics sources, as well as the use of professional software. Their dimensions generated greater dissatisfaction among university students and teachers. In general, 61.25% of the students indicate their dissatisfaction with the low technological resources and internet connectivity than in relation to Rhongo and Piedade (2022) who obtained 83%.

In addition, they presented inadequate classroom infrastructures for current times, such as equipment, furniture and teaching materials. In agreement with Mendonça (2014), Campira et al. (2021) infrastructure and its internal components are basic factors for teaching and learning in students.

Therefore, it was demonstrated that access to technology influences students’ abilities to participate and receive authentic learning. At the same time, various criteria and critical views on digital technologies for education emerge, but in the context of digital teaching and competence with eco-responsible use (Barragán et al., 2020). In the same context, several researchers have shown that the use of technologies provides new opportunities to expand FC methodologies such as PBL (Seibert et al., 2013, Duan et al., 2021, Campillo and Miralles, 2021).

An important finding was regarding the variable of students’ learning in the UC in the sections of research project development and field practices, where 90% were satisfied with a Likert scale of 4.41. The possible results in the UC, is a product of the improvement of the study plans of the Engineering careers in Cuba. As significant factors is the integration of subjects, and insertion of integrative projects (IP) in the strengthening of competencies, learning and interdisciplinary research (Rivero et al., 2017). In other aspects, from the curriculum it recognizes and promotes state-owned enterprises within its management model, through the University-Business relationship. Indeed, it enables the direct exchange of students in the identification of problems and possible solutions in productive enterprises. All of which generates a broad profile training and motivational environment in students (Artola et al., 2019).

In general, the survey showed that students acquire knowledge with greater interest in research projects and field practices. The results are possible due to an adequate environment based on the interests and motivations of the students. Likewise, self-management of learning in the use of the educational resources designed and their environment in invested learning, despite its low rate at UM. The design of projects linked to real situations that students will face in their professional life allows us to verify that it stimulates creative and critical thinking. The effectiveness of different pedagogical approaches such as PBL, based on research projects and case analysis, proved to contribute to the delivery of knowledge and content in higher education (Salas et al., 2014, Forcael et al., 2015).

The high percentage above 80% of satisfied students in UC and UP is also due to the fact that, students are more motivated by the actual knowledge they will face in their professional life (Yew, 2016 and Argaw et al., 2017). That, in comparison, with UM students, their concern was diversified in several
variables such as psychological, socioeconomic and geographical. Also, the teacher plays a key role in designing the activity, guidance and feedback of the problems, as well as personalized and group teaching. It is relevant that students develop self-directed skills and acquire knowledge for life. The idea of merging FC and PBL under the STEAM education modality is fundamental for the close link between teacher and student and the new demands of higher education.

Although it is true that several universities have implemented FC associated with STEAM curricula, there are still limitations in the teachers’ own didactic experiences and in the evaluation mode in a virtual environment (Aguilera et al., 2017). In this sense, other limitations have been found in the research, such as the refusal by students to dedicate some hours to self-learning due to scarce resources for its implementation as is the case of students at UM.

Hydrology as an interdisciplinary science has been incorporating more and more genuine problems that STEAM educators, predictive analytics with a machine learning approach are a must. Which requires a high level of technology and in turn induces the student to need a higher level of knowledge, mathematical and computational thinking. New hypotheses can be formulated for future research on which teaching method is more feasible to incorporate machine learning in the hydrology career with students in a previous moderate computational preparation. But teaching needs to be developed with students as a novel method of data analysis that automates analytical model building (Shen et al., 2021).

Finally, the role of the teacher in the fusion of FC and PBL tends to be significant in consolidating learning from a motivational position in which he involves students in real experiences or natural phenomena that affect society. Therefore, it can generate contradictions to their initial hypotheses and thus stimulate discussion. These are aspects that contribute to the student to establish connections between the concepts and ideas studied before class. In addition, they encourage the student in the development of autonomy, leadership and self-esteem when he/she has difficulties or lacks skills. The fulfillment of the hypothesis is confirmed by the fact that the composition of the dependent variables integrated in STEAM education, FC and PBL, demonstrated through the survey that, increases skills, commitment and learning in the student, making it part of their professional training in an integral way and with full sense of social responsibility.

The results of the present study have shown that the practical aspects of teaching hydrology should be more present in scenarios in which the student visualizes social problems linked to technology as one of the tools to accelerate the processing and interpretation of information. At the same time, the mastery of pedagogical tools by the teacher is key to achieve interactivity, motivation, collaborative learning and formative evaluation.

It can be specified that the students’ evaluations and capacities showed differences among the three universities based on the evaluation system, the most unfavorable being at UM. However, an increase in the degree of motivation of the students in both modalities of the educational service could be evidenced. Finally, at the end of the course, many continue with their projects to obtain a degree in Civil Engineering and, in other cases, publish their results in indexed journals.

As a result of methodological integration in universities, it was found that students tend to show greater interest and concern for the development of activities. They seek to interrelate more with technological aspects, facilitating skills in statistical processing and reasoning. Creative and critical thinking about real problems.

The results of the evaluations during the 10-year period show the existence of an exponential function with a favorable positive slope. This is indicative of a methodology that results in the student presenting fewer theoretical problems and consequently becoming more involved in the contents in class (Del Savio et al., 2023). Nevertheless, negative slopes have been reached in the exponential function with greater influence in the UM, due to limitations imposed by the use of Information and Communication Technologies (ICT) in university education. In spite of all this, several students requested improvement in their continuous, partial and final evaluations.

As a notorious discovery, it was found that UM and UP promote more surface hydrology topics, than surface and groundwater hydrology in relation to UC. Their causes are due to geographical situations and climatic contexts of each country. At the same time, it was visualized that affective interactions with social phenomena improve participation and learning.
4. Conclusions

The fusion of the FC and PBL methodology for the development of generic competencies and student learning in the hydrology course resulted in an instrument of successful reliability according to Cronbach’s alpha, which can be applied in other geographical conditions of continents and intercultural diversity.

The Kolmogorov-Smirnov, Spearman normality test indicated that there are significant differences in the methodological integration and the traditional model. The application of the FC and PBL was accepted with joy and enthusiasm by the students according to the Content Validity Index reflected in the improvements in their partial and final evaluations.

Students at the University of Peru showed the best satisfaction behavior with the FC and PBL methodology with 89.92%, in relation to students at the University of Cuba 80.12% and finally students at the University of Mozambique with 46.14%.

Strengths and weaknesses of generic competencies were found in the universities, such as those related to learning (CRA) and those related to values (CRV). While, the learning of the subject generated greater well-being, emotional state and interest in the course in the sections of laboratories and project development of 91.02%, 77.87% and 42.27% in the students of UP, UC and UM universities respectively. In these sections the student achieved the multidisciplinary approach through the use of computers, software and multimedia that allows an education focused on ascending learning rhythms in their independent way and group work. It was observed that over time the FC and PBL approach, promotes lifelong learning with local and global problem solving perspectives that include in different basic skills, from engineering design to responsibility and professional ethics.

It was demonstrated that the effective scope of the methodology requires teachers with competencies and rigorous knowledge of science, tools and technologies to carry out the activities. Notoriously, universities with scarce technological and computer resources, Internet connectivity, didactic materials and infrastructure, showed weak student motivational component. The value on the Likert scale was 3.76 and 3.11 which represented 33.93% and 61.25% of students surveyed from UC and UM respectively. It is necessary for governments to influence public universities to reduce the digital divide and consequently improve the quality of education. The STEAM educational approach, FC and ABP methods should be integrated to the rest of the disciplines related to the hydrology career for engineers, under the didactic and pedagogical principles so that creativity is not only focused on the teacher. In this sense, the benefits achieved by students in all areas of knowledge are expanded. A significant finding was from the contexts and situations in which the methodology was developed, it is inferred that there are geopolitical environments of scientific knowledge that prioritize types of skills and knowledge over other less significant ones. In a comparative approach to the Universities of Cuba, Peru and Mozambique, it was observed the different ways of organizing the curricular design and its effect on the topics of the course, which incur in the purpose of knowledge and learning. Therefore, an analysis of the curricula between countries would be recommended for future work. The benefits of conducting this research lie in the novel impact of methodological typologies, as well as in enriching and homogenizing teaching and learning criteria in universities at a global level.

The second finding of the research is the positive impact of the FC and PBL methodology, which provide a comprehensive pedagogical tool to address critical situations of sustainable development in different regions of the world through the teaching and learning process. Further study is needed to understand the effect on the subject of hydrology as an interdisciplinary science. In response to the above conclusion, future work should be expanded on the number of instrument subjects, earth science subjects, and academic performance to assess the impact.

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