

# **Enhancing Academic Performance in Operations Research through Cooperative PBL in a Distance Learning Environment**

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## **Abstract**

Professors have had academic performance problems during the pandemic associated with their learning models. Primarily due to lack of preparation in distance learning resulting from the suddenness of the transition. One of the areas most affected were STEM subjects, which had advantages in a traditional face-to-face environment. The pandemic presented a challenge, especially for the teaching of Operations Research. At the beginning this subject was taught using a model of the physical environment with some digital tools, however the performance was not as expected. The study focuses on demonstrating the improvement of academic performance in the Operations Research subject using Cooperative Project Based Learning. Method: for the research, the Cooperative PBL learning model was applied on measurement indicators based on the quality assurance model from ICACIT accreditation, both within a distance learning environment during the pandemic. Performance data were taken from one semester of traditional distance learning and then from 2 semesters applying Cooperative PBL by observing and measuring student outcome performance. After the study, performance indicators were compared and an evolution was found by applying Cooperative PBL. Academic performance was more promising over time, finding a difference between the first experience versus the later application of the model. As for quantitative results, the academic performance of the student's increased up to 3.00%, 100% of students passed the subject. As qualitative results, the students obtained recognition in university contests, generating a better intrinsic motivation, improved their critical thinking and gave value and meaning to their learning.

## **Keywords**

Cooperative PBL, Operations Research, outcomes assessment model, PBL, PjBL, Quality assurance model, STEM learning,

## **1. Introduction**

As educators, professors look for ways to motivate students. Engineering professors often find students lack motivation due to the highly technical nature of many courses, lack of guidance to relate topics to their field of study, or lack of basic engineering knowledge (Ripoll et al. 2023). So as a result of these searches many ideas arise to preserve motivation. Some of them show that using Project Based Learning has many advantages, mainly because of the application of the ideas in real facts. Below we review some experiences with positive results in academic performance.

Project-based learning (PjBL or PBL) could be an effective and proven alternative to traditional teaching. Professors could introduce PjBL in major engineering courses, and it is expected, from the positive results in several areas, that students will obtain better learning outcomes than those of traditional teaching (Cheng-Huan and Yong-Cih 2018). Beyond teaching in engineering subjects, it is also suggested that teachers involved in technology education in general, deepen their understanding of PBL by studying the theory of this approach, since a proper understanding of PBL is crucial to ensure that it is correctly applied and used in favor of educational improvement in technology. (Rauscher 2013). In PBL, the student is the center of the teaching-learning process, the professor's role is that of a facilitator who presents students with resources and guidance during the process. It is more common to use PBL in a physical classroom environment, but during the pandemic it has been shown that in a distance or hybrid classroom environment, it makes a positive contribution in supporting teaching (Ceh-Varela et al. 2023).

Researching more successful experiences, the application of PBL or PJBL in teaching programming was found. After its application in the development environment of a joint programming project in a problem-based environment, the results found showed that it requires teamwork skills, cooperation, responsibility and, sometimes, involves unplanned dependencies. Team members need to balance their responsibilities, combine their contributions, synchronize their programming activities, and coordinate their efforts in order to achieve success. The skills developed can prepare programming students for the future demands of the industry (Havenga 2018).

This research is generated from the teacher's search to improve his methodology so that this is evidenced in the quantitative and qualitative results (learning) of his students. The research had novel and very important elements in its experimentation. The subject, Operations Research, whose objective is to investigate organizations by applying mathematical methods and models for the solution or optimization of problems in various areas, for which a team approach is necessary to propose better solutions from different perspectives (Hillier 2010). The virtual learning environment in a critical situation for the context as was the pandemic was full of changes for the learner at a personal and academic level. In addition, distance learning and PBL were found to have a strong influence on the increase of creative capacity (Yustina et al. 2020). These elements allowed experimenting with different methodologies to improve student learning. Initially, a virtual modeling of traditional teaching was carried out, with little success in the academic results of the students, and later the collaborative PBL methodology was incorporated in a virtual environment which improved the capabilities and skills of the students.

## **1.1 Objectives**

Based on the experimentation of a variety of methodologies, the research proposed to use Cooperative Project Based Learning (PBL) in a Distance Learning Environment in order to enhance academic performance in Operations Research, a STEM course, mandatory in many Engineering curriculums.

The research also aims to create awareness in students about the problems of their region, encouraging not only their analysis, but also the proposal of application projects that help solve real problems.

Finally, the research, in addition to measuring student outcomes, managed to improve them through the application of cooperative PBL.

## **2. Literature Review**

Initially, with the sudden change from physical to virtual classrooms due to the pandemic, we tried to use traditional learning, enhancing it with cloud-based tools, but it wasn't enough. On the other hand, Operations Research is a subject that requires a lot of practice and motivation, thus difficulties were experienced in the learning process and reflected in the student's results. The pandemic also made the students more aware and sensitive to the problems in their region. The above was a cause for concern and analysis, giving place to the present research. Subsequently, after the review of experiences and bibliography, the Cooperative PBL methodology appeared as a proposal to increase students' results.

It is also worth mentioning that Operations Research is in the STEM course category and in order to measure student outcomes, a quality assurance method based on the ICACIT accreditation system (accrediting agency specialized in engineering programs) is used. ICACIT defines student outcomes as the skills, knowledge and behaviors that students acquire throughout their progress in an academic program (ICACIT 2023). In this quality model, student outcomes are defined and each subject contributes to the measurement of these outcomes (Moreno et al. 2020).

Now we will review the state of the art of PBL: cooperative PBL, distance learning environment, and measurement of student outcomes.

Project-based learning (PBL) is a methodology that presents benefits for students and teachers. It engages students in real-world problems, resulting in a product that is applicable to their context, allowing them to acquire skills and knowledge useful for life (Chen and Yang 2019). In educators, project-based learning allows them to develop leadership competencies for change, which would enable them to leverage these competencies for the benefit of their students' learning (Fatemeh 2023). There were found positive effects on student academic achievement in PBL compared with traditional instruction, providing reliable evidence that PBL is much more effective with regard to enhancing students' academic achievement (Chen and Yang 2019). Some research suggests that PBL enforces a process of creating new knowledge that allows students to test and realize their ideas in any way they wish, which fosters their competence and capacity for innovation. It then suggests the need for higher education teachers to adopt project-based learning. (Gomez and Rodriguez 2022).

Project-based learning is a pedagogical approach that involves students working on real-world problems or projects over an extended period of time. To propose a model, we searched among several models or frameworks used in higher education. We then extracted the most relevant stages as follows

- Identify a real-world problem or project: The first step in PBL is to identify a problem or project that is relevant and meaningful to students. (Buck Institute for Education 2020)
- Design a driving question: Once a problem or project has been identified, a driving question should be designed that guides the students' inquiry and investigation. (Buck Institute for Education 2020)
- Plan and research: In this phase, students plan and research their project, using a variety of sources and tools to gather information and develop a plan of action. (Jaaska 2022)
- Create and develop: In this phase, students use their research and planning to develop a solution or product that addresses the driving question. (Barron & Darling-Hammond 2016)
- Share and evaluate: The final phase of PBL involves sharing the solution with others and evaluating its effectiveness. Students can present their work to peers, experts or community members, and receive feedback that will help them in their learning. (Boss & Krauss,2018)

Project-based learning (PBL) has shown widespread improvement in student outcome measures, improving student engagement and long-term learning effectiveness. In a student outcome assessment, the PBL intervention was shown to be highly successful and positively influenced test scores. It was also found that, in terms of gender, female students showed a higher rate of engagement and greater improvement than their male counterparts. (Zhang 2023). Another important indicator of professional programs is the employability index. In a PBL-based experiment, students were given a realistic global task to solve in interdisciplinary teams; where industry representatives acted as advisors and teachers. The results were that students achieved employability competencies. In addition, the benefit was mutual, because the industry representatives learned about new digital solutions and programs while meeting new talent (Wyke et al. 2022).

The interest of this research was to apply PBL in higher education, so after reviewing some research we found a literature review with recommendations from teachers to teachers that was very useful and meaningful. This research reviews a series of experiences and compiles successful techniques that result in practical advice to teachers who want to apply PBL, some of them are:

- Time management, getting started (guiding students)
- Establishing student self-management
- Manage student groups (promote full participation and track the progress of each group)
- Establish external collaborations
- Maximize the use of technological resources. (Kokotsaki et al. 2016)

The study of Syahril (2020) shows a significant difference between the class with the PjBL and Cooperative PjBL model. The average of students with the implementation of the C-PjBL model is higher.

After the review we can see that the PBL methodology has several advantages, especially in subjects that require practical application. It has also been successfully applied in basic and higher education, favorable to the improvement in the measurement of student results and therefore the achievement of learning objectives. Empirical research shows the success of project-based cooperative learning involving even industry representatives, to give the student a more real and closer experience with the development of their professional competencies.

About distance learning, there is and always will be a debate about the future of online teaching and learning in higher education, much more so now with the incursion of Artificial Intelligence (AI).

One study state that distance or online learning has increased in importance in higher education due to the COVID-19 pandemic. Distance learning is characterized by the use of digital technologies such as learning management systems (LMS), online collaboration tools, and video conference software.

This mode of education offers flexibility for students to learn at their own rate, while still interacting with their professors and peers through forums, chat rooms and videoconferencing. In addition, students have access to digital resources such as online libraries, digital textbooks and multimedia content. The authors also highlighted the importance of assessment and feedback mechanisms in online education to evaluate students' progress and provide feedback on their performance. Finally, online learners may need technical assistance to solve problems related to software, hardware, or connectivity (Chan et al. 2021).

Some challenges and opportunities of online or distance learning from the perspective of teachers, highlights the need for more research and support to ensure effective teaching and learning in the post-pandemic world. (Chan et al. 2021)

The COVID-19 pandemic also affected many areas of education, such as medical education, where technology was used to adapt to the new circumstances. A variety of technologies, such as videoconferencing, online learning

management systems and virtual simulations, were used to provide educational opportunities for students (Chick et al. 2020)

### 3. Methods

The methodology used in this research was Project Based Learning, developed from a collaborative teamwork perspective. PBL was applied in a difficult, non-traditional context, during the pandemic, called Distance Learning Environment. In addition, a quality assurance model was applied to measure learning outcomes based on the ICACIT accreditation model.

Project-based learning (PBL) is a methodology, a form of learner-centered teaching based on three constructivist principles: first, learning is context-specific; second, learners actively participate in the learning process; and third, they achieve their goals through social interactions and the exchange of knowledge and experiences. (Kokotsaki et al. 2016)

For the process model we used a project-based learning process guide, which includes essential design steps to drive 21st century learning. This is the Gold Standard PBL model, which consists of seven essential elements for project design (Buck Institute for Education 2020):

1. Challenging Problem: Projects should be designed around a real-world problem or question that is relevant and engaging to students (Buck Institute for Education 2020).
2. Sustained Inquiry: Students should be engaged in a process of formulating questions, finding resources, and applying information to solve a problem or answer a question. This process should include opportunities for feedback and reflection. (Buck Institute for Education 2020).
3. Authenticity: Authenticity helps students understand the importance of their learning. Projects should be designed to reflect the complexities of the real world, with activities that simulate the work of industry professionals. (Buck Institute for Education 2020).
4. Student Voice and Choice: Students should have a say in what they learn, how they learn it, and how they demonstrate their learning. (Buck Institute for Education 2020).
5. Reflection: Students should engage in reflective activities that help them evaluate their own learning and think about how they can improve their work. (Buck Institute for Education 2020).
6. Critique and Revision: Students should receive feedback on their work and have the opportunity to improve their projects. This helps to foster resilience and persistence (Buck Institute for Education 2020).
7. Public Product: Students should create a product that has value beyond the classroom, such as a presentation. The product should be shared with an audience, such as community members or subject matter experts. (Buck Institute for Education 2020).

Figure 1 shows the graphical representation of this process as a cycle.

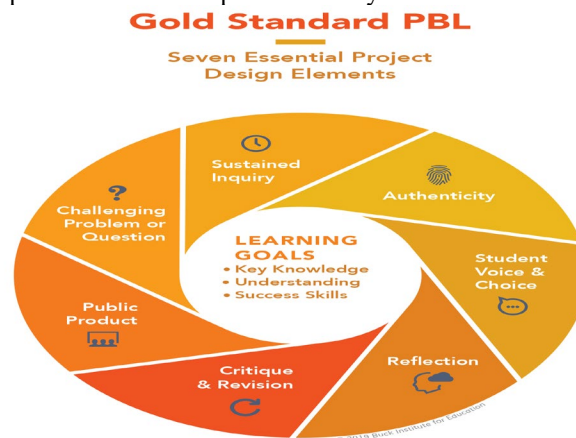


Figure 1. Gold Standard PBL (Buck Institute for Education 2020)

The research will also follow the six key recommendations on the basis of the evidence (Kokotsaki et al. 2016)

1. Student support: Guidance and support for students; time management and student self-management, safe and productive use of technology resources.
2. Teamwork: Ensuring that students share equal levels of participation and collaboration.
3. Balance between teaching and work: Ensure that students develop knowledge and skills before engaging in independent work.

4. Assessment emphasizes reflection and self- and peer-assessment.
5. Student choice and autonomy throughout the PBL: This will help develop a sense of ownership and control over their learning.
6. Teacher support: Regular support for teachers through networking and professional development opportunities. Figure 2 shows a scheme of these recommendations.

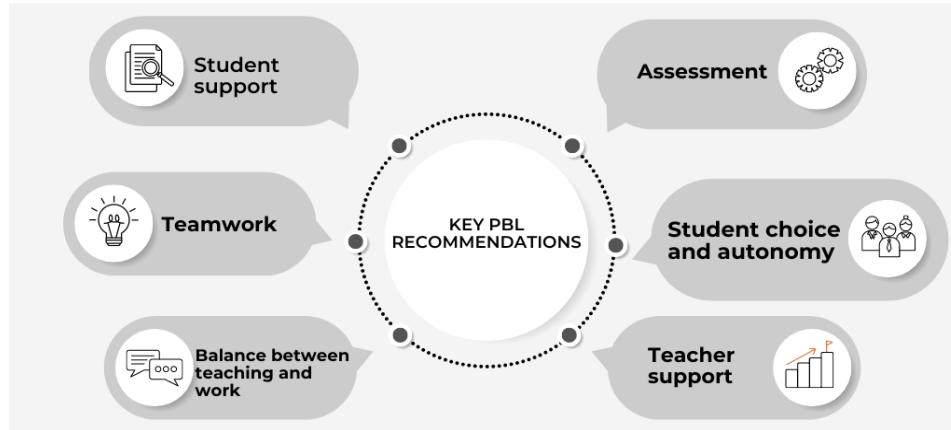


Figure 2. Key PBL Recommendations

PBL was developed in a Distance Education environment and from the literature review we extracted some technologies, tools and recommendations, here is the list of recommendations associated with the tools and technology we used:

1. *Choose a reliable and user-friendly video conferencing platform.* We used Google Meet.
2. *Provide clear guidelines for participating in virtual meetings.* It was established in the course syllabus.
3. *Use a learning management system.* We used Google Classroom and Moodle
4. *Use online discussion forums.* We used Google Classroom, Moodle and WhatsApp.
5. *Develop a system for tracking and assessing.* We used Google Forms, Moodle
6. *Provide technical support including troubleshooting assistance for software, hardware, or connectivity issues.* Professors provided technical assistance within their scope, then the help of the technical assistance area called RCU UNSAAC was requested.
7. *Communicate.* There was regular communication with students about course updates and feedback.

#### 4. Data Collection

Data collection was conducted during the pandemic, within a distance learning environment from 2021 to 2022.

In the year 2021, semester 2021-2, the results of the academic performance of the students of the Engineering program were obtained, who from a qualitative perspective, showed low motivation, which was reflected in grades with low averages and even abandonment of the course. The year 2022 begins with the application of the Collaborative Project Based Learning methodology, measuring its results during semesters 2022-1 and 2022-2.

It is also important to mention that grades in Peru are vigesimal, that is, from 0 to 20 points, with the minimum passing grade in the institution being 14 points. The status, a qualitative value, is a value that is used in the academic field in order to give a nominal value to the range to which the grades belong. The status Approved (Pass) is assigned for averages between 14 and 20 points, Fail for averages between 10 and 13 points and Reprobate for averages between 0 and 09 points. (UNSAAC 2017). Table 1 shows the summary data of academic performance by semester, processed during the research. In detail it shows the average grade, the variation between semesters, which will be explained later, and the qualitative value or nominal value associated with the quantitative average.

Table 1. Academic performance by semester

Semester	Average grade	Variation	Status
2021-2	14,4	0,00%	Approved Minimum
2022-1	14,9	3,00%	Approved
2022-2	15,3	3,12%	Approved

## 5. Results and Discussion

### 5.1 Numerical Results

Below there are tables containing the results of the research from different indicators, these indicators allow observing, analyzing, verifying and evaluating the improvement of student results from different perspectives. Tables show outcomes by semester, by status (nominal value), by year of study plans, among others. Table 2 shows the percentage variation between semesters.

Table 2. Percentage variation between semesters

Semester	2021-2	2022-1	2022-2
Value	14,436	14,870	15,333
Percentage variation	-	3,00%	3,12%

Table 3 shows the percentage of students by status (Pass, Fail, Reprobate) and by semester. The last column also shows the variation in student status between semesters.

Table 3. Percentage of students by status

Semester	Number of students	% Pass	% Fail	% Reprobate	%Variation Passed
Sem 2021-2	60	75,00 %	21,67 %	3,33 %	-
Sem 2022-1	69	76,81 %	23,19 %	0,00 %	1,81 %
Sem 2022-2	36	100,00 %	0,00 %	0,00 %	23,19 %

Table 4 shows performance by curricula, the program has 2 curriculums. Students from both curriculums assist in the same course. The table shows the difference of average grades between semesters and curriculums.

Table 4. Performance by curricula

Semester	Average grade- curricula 2016	Average grade- curricula 2020
Sem 2021-2	15,53	12,91
Sem 2022-1	14,83	14,89
Sem 2022-2	16,00	15,00

In addition, accredited professional programs have an ongoing responsibility to measure the achievement of their students. The measurement is done through indicators called student outcomes, which are the product of the association of subjects to student outcomes. The Operations Research subject has been associated with the following student outcomes. Table 5 shows the student outcomes from ICACIT (ICACIT 2023).

Table 5. Student outcomes from ICACIT

Student outcomes	Description
A	Computing Knowledge: The ability to apply knowledge of mathematics, science, computer science, and a computer specialty appropriate to the student's and the discipline of the program. (ICACIT, 2023)
B	Problem Analysis: The ability to identify, formulate, research literature, and solve complex problems in computing and other relevant disciplines in the domain. (ICACIT, 2023)
C	Individual and team work: The ability to perform effectively as an individual, as a member or leader of varied teams. (ICACIT, 2023)

Table 6 shows the consolidated percentages of student results obtained for the semesters evaluated in the research: 2021-2, 2022-1 and 2022-2.

Table 6. Student outcomes percentage

SEMESTER	% SO-A	% SO-B	% SO-C
2021-2	73,27%	78,55%	65,09%
2022-1	71,01%	74,78%	80,58%
2022-2	76,67%	70,56%	84,44%

## 5.2 Graphical Results

Figure 3 shows the average grades of the group of students per semester. In semester 2021-2 the average grade was 14.4, in this semester PBL was not applied. In semesters 2022-1 the average grades were 14.9 and 2022-2 the average grade was 15.3, in both semesters PBL was applied.

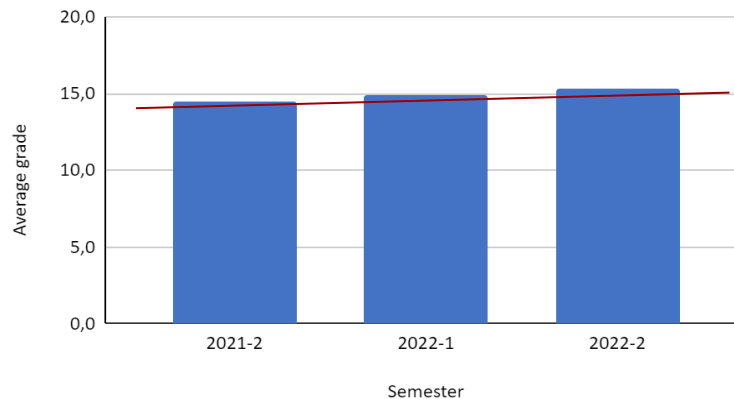


Figure 3. Academic performance by semester

Figure 4 shows the percentage of students by status and by semester.

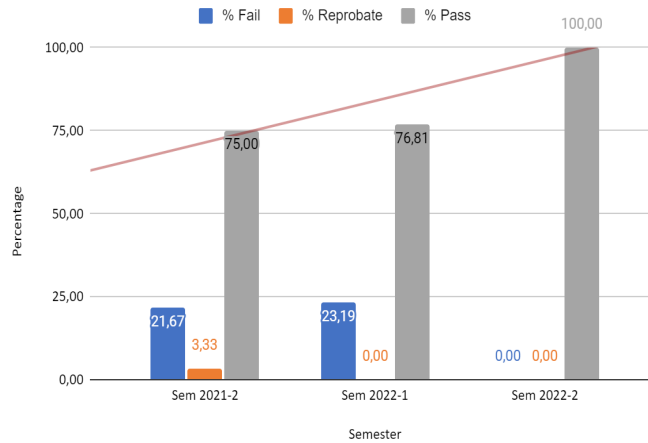


Figure 4. Percentage of students by status

Figure 5 shows academic performance by curricula, there are 2 curricula. Figure 4 shows the difference of average grades between semesters and curricula.

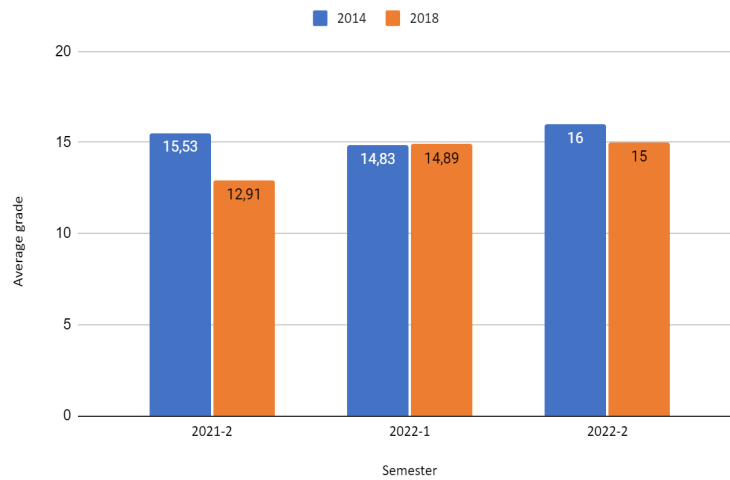


Figure 5. Academic performance by curriculum

Below are charts of student outcomes achieved by semester. It is also necessary to clarify that the program has a minimum compliance percentage (target percentage), which is set at 70%. This proposal comes from a compilation of literature related to Accreditation (Tirado-Mendoza *et al.* 2020).

Figure 6 shows the achievement of student outcomes in percentages for semester 2021-1. We can observe 73.27% achievement of outcome A, 78.55% achievement of outcome B and 65.09% achievement of outcome C.



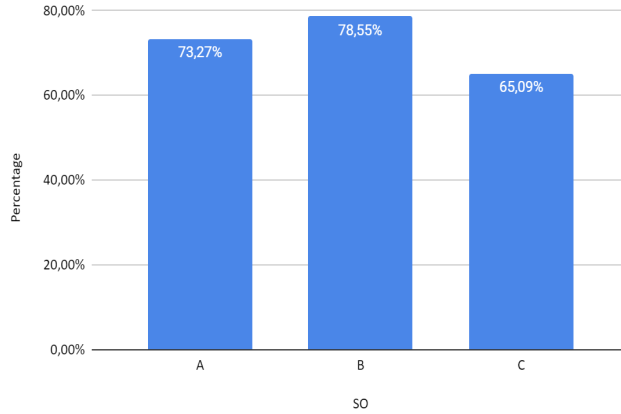


Figure 6. Percentage of student outcomes (SO) semester 2021-2

Figure 7 shows the achievement of student outcomes in percentages for semester 2022-1. We can observe 71.01% achievement of outcome A, 74.78% achievement of outcome B and 80.58% achievement of outcome C.

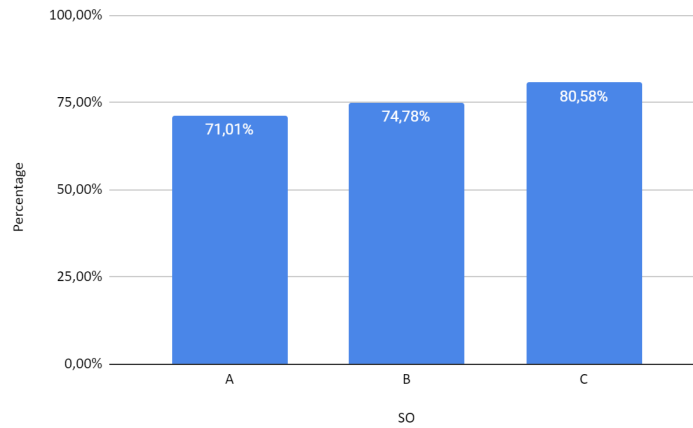


Figure 7. Percentage of student outcomes (SO) semester 2022-1

Figure 8 shows the achievement of student outcomes in percentages for semester 2022-1. We can observe 76.67% achievement of outcome A, 70.56% achievement of outcome B and 80.44% achievement of outcome C.

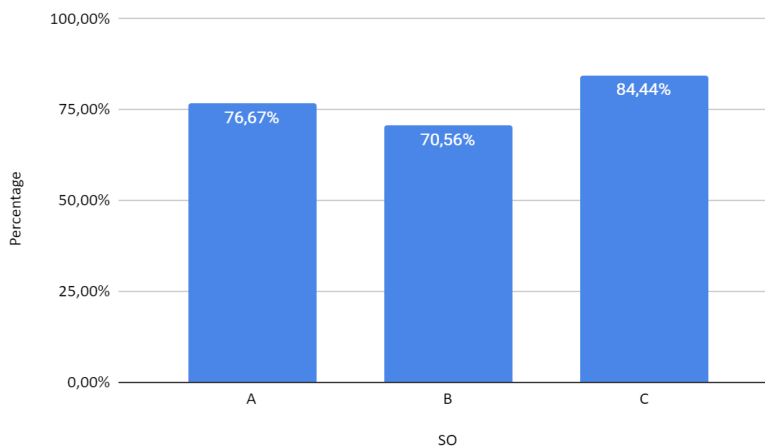


Figure 8. Percentage of student outcomes (SO) semester 2022-2

### 5.3 Proposed Improvements

Through Cooperative PBL, improvements were obtained in students' academic performance; these findings are evidenced by quantitative and qualitative results. The quantitative results come from measures of important indicators of academic performance. Below is a review of these quantitative indicator improvements:

First in Table 1 Academic performance by semester in the variation column shows a quantitative increase in the average grades of the Operations Research students. The use of the distance learning environment of this course starts in semester 2021-2, with a traditional teaching with the use of digital tools. Subsequently, in semesters 2022-1 and 2022-2, collaborative PBL is applied, showing an increase in the average grade of 3.00% and 3.12%.

Second, Table 3 Percentage of students by status, in the variation column, shows a percentage increase in the number of approved students of 1.81% and 23.19%,

Third in Table 4. Performance by curricula, the difference between average grades per curriculum is 2.62 in semester 2021-2 and decreases in semester 2022-2 to 0 and 2022-2 to 1.00.

Finally, Figure 9 shows Percentage of student outcomes (SO) by semester, semester 2021-2 shows a low achievement of student outcome C (under the target percentage which is 70%) in contrast semester 2022-1 and 2022-2 shows better results over the target percentage.

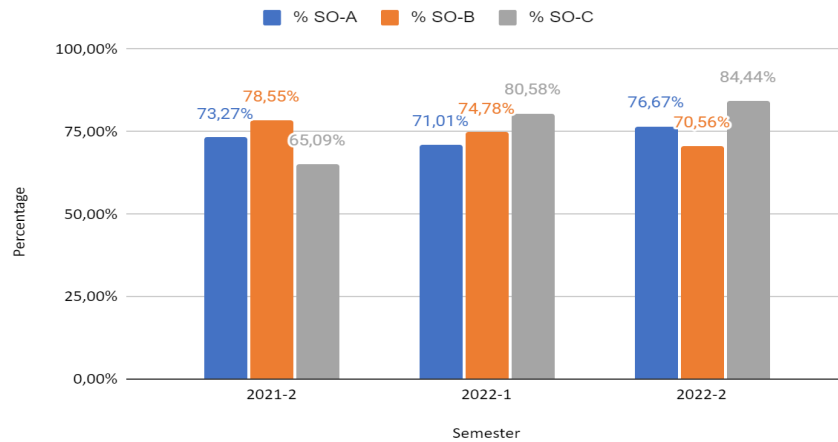


Figure 9. Percentage of student outcomes (SO) by semester

As qualitative results, first professors designed the model for applying cooperative PBL based on the Buck Institute for Education's Gold Standard PBL model. Table 7 shows how we follow the Buck Institute for Education's Gold Standard PBL model in designing projects.

Table 7. Gold Standard PBL and project design.

<b>Gold Standard PBL model</b>	<b>Methodology and techniques applied on the case study</b>
Challenging Problem or Question	Professors gave examples of the most relevant and urgent problems in the region. They then assigned the students to come up with a solution using Operations Research models or techniques. We divide students into teams of 3 to 4 members to apply a cooperative PBL approach. So, they come up with better ideas and improve their teamwork skills.
Sustained Inquiry	The teachers established a deadline. Within this a revision cycle was designed consisting of 3 stages: asking questions, finding resources, and applying information. This cycle was repeated weekly until the project was delivered. A weekly exhibition was scheduled. Oral Presentation of the project.
Authenticity	The projects had to be solutions applicable to the problems of local and regional reality, with data extracted from local institutions or organizations, which ensured their authenticity.
Student Voice and Choice	In order to increase the students' commitment and motivation, in the phase "Sustained Inquiry" they were given the space to clear technical questions and comment on their learning.
Reflection	We designed a project rubric taking into account the student's self-assessment. After the partial and final reviews, they received feedback from the professor.
Critique and Revision	The cycle designed in the "Sustained Inquiry" stage allowed for ongoing review of the students. Project rubric aligned to the student outcomes of the quality model was used.
Public Product	The institution promotes public exhibitions of projects, competitions and awards to students, which motivates the teacher and students to continue presenting projects applicable to the reality of their region with great potential to be presented at regional and national level.

Then based on the methodology, its characteristics and on the 06 key recommendations in Figure 2. Table 8 below shows the actions planned and executed for each recommendation.

Table 8. Key recommendations and Methodology and techniques

<b>Key PBL recommendations</b>	<b>Methodology and techniques applied on the case study</b>
Student support	Professors assumed the role of guides, encouraging student self-management and setting realistic deadlines.
Assessment	Project evaluations were carried out based on rubrics aligned to the student's outcomes, where the student was previously aware of the grading criteria.
Teamwork	Emphasis was placed on teamwork, collaboration and balanced work, distributing roles and evaluating their fulfillment with contributions and suggestions.
Student choice and autonomy	The projects encouraged students' analysis and critical and autonomous thinking. From this analysis, they had to come up with a creative idea in which the use of Operations Research models could contribute to the development of the project.
Balance between teaching and work	The students visited the reality of each project to make a correct diagnosis and to make a more realistic proposal, so they approached the professional work in which they will develop in the future.
Teacher support	The institution promotes public exhibitions of projects, competitions and awards to students, which motivates the teacher and students to continue presenting projects applicable to the reality of their region with great potential to be presented at regional and national level.

Second, students were motivated to create awareness of the problems in their region, encouraging the analysis and planning of application projects that help solve real problems. The teachers previously provided knowledge about the main Operations Research models and techniques they can use, as well as background examples. Students learned Operations Research models such as Queueing Theory, Game Theory, Operations Research Business Analytics (National Taiwan University 2020), Markov Process, Linear and Nonlinear Programming, among others. Table 9 shows the most representative projects presented in the subject

Table 9. Best Projects on Operations Research subject

Semester	Project Title
2021-2	None
2022-1	Reduction of waiting time to avoid crowding and disorder in poultry service agencies using Queuing theory.
	Application of Queuing theory in traffic lights to improve mobility in the city of Cusco.
2022-2	Business Analytics for the implementation of new methods of payment in minimarkets.
	Application of Queuing theory for the health management of the regional hospital of Cusco.

Finally, these representative projects were publicly presented for the program and received recognition which generated greater intrinsic motivation, enhanced their critical thinking and gave value and meaning to their learning.

## 5.4 Validation

The primary purpose of this study was to enhance academic performance and student outcomes in Operations Research using PBL or PjBL in a distance learning environment. We now present the analysis of our findings and support of our proposal.

Beier et al (2019) outlines as an area for future research the use of PjBL to attract students to STEM programs. We also believe that from the positive results we got in regular student grades, PBL or PJBL may be applicable in strategies for capitation or retention of students in Engineering programs.

COVID19 is an unprecedented event that will change the way we educate for at least the next few months or more. It will require innovation and cooperation from students, teachers and institutions (Chick et al. 2020). Our project also found that. COVID19 is an unprecedented event that will change the way we educate for at least the next few months or more. It will require innovation and cooperation from students, teachers and institutions. The results have shown that in a first semester involving only digital tools, it did not have the expected results in academic performance and neither in the achievement of student outcomes. Therefore, according to the (Chick et al. 2020) research, after looking for innovative and cooperative options, we managed to improve the academic performance and the achievement of student results. Therefore, the affirmation of this research is valid.

Digital tools can offer new opportunities for collaborative learning, where students can work together to solve problems, discuss ideas, and achieve active learning. Digital media can increase student motivation and engagement and improve learning outcomes. Digital media can transform traditional teaching-learning practices and offer new opportunities for collaboration, creativity and innovation in education (Gan et al. 2015). In contrast to what is stated in this article, in a distance learning environment, the use of digital tools was not sufficient. In our research, in addition to digital tools, we used cooperative PBL to achieve better results.

Finally, distance learning and PBL have become increasingly popular teaching strategies in this era. PBL in a distance learning environment offers a unique opportunity for students to:

1. Collaborate with authentic outcomes,
2. Work on real projects relevant to their field of study, and
3. Develop the critical thinking, problem solving, and communication skills

All of the above are necessary abilities for success in this era.

A distance learning environment, PBL can be an effective way to provide students with an active and engaging learning experience. So, it can be an asset for teaching STEM courses. Operations research is not only about learning mathematical models but also about solving problems, so PBL can be an effective way to solve problems through projects that allow students to obtain experiential learning.

## 6. Conclusion

In this study we have proposed a new methodology in addition to the traditional teacher-directed instruction. Cooperative PBL has become a great methodology to improve academic performance in many qualitative and quantitative aspects.

Teaching Operations Research can be a difficult task due to students' perception that STEM subjects are complex, stressful, and require memorization. However, Project Based Learning (PBL or PjBL) can be an effective approach to enhance students' learning experience by allowing them to apply their skills and knowledge in real projects.

PBL provides a student-centered learning environment that encourages active learning, critical thinking, problem solving, and collaboration. By participating in PBL, students can improve their understanding of subject matter, develop their communication and teamwork skills, and increase their confidence in tackling real-world problems. Therefore, adopting PBL in Operations Research teaching can provide a valuable opportunity for students to enhance their learning process and improve their academic performance.

The research took advantage of the empathy and sensitivity generated by the pandemic to highlight the problems and needs of the country. The students made a diagnosis and critical analysis of their reality to later propose projects that improve or mitigate the problems of their region. All this with the use of mathematical models and Operations Research techniques. So, the research fulfilled the purpose of creating awareness and challenging the students' critical thinking.

In addition to positively influencing grades, the methodology also improved student outcomes, defined as the skills, knowledge and behaviors that students acquire throughout their progress in an academic program. This contributes directly to the student's professional development and to the fulfillment of the graduate profile, beyond just improving grades.

For an efficient use of a distance learning environment, it is important for teachers and students, permanent training, technical support and flexible schedules that would allow to improve the application of PBL. It is also necessary to innovate and adapt STEM education so that students continue to receive quality training even in these contexts.

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