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VIRTUAL GALLERY OF MATHEMATICAL PROBLEMS: COOPERATIVE LEARNING, INTERACTION AND SOCIALIZATION

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Abstract

The importance of cooperative learning lies in its improvement of social skills, comprehension, retention and motivation, preparing students for teamwork environments in the professional world. This article describes the implementation of cooperative activities in mathematics education in a university setting. Specifically, it addresses the creation of a virtual gallery of problems and exercises. It describes the tasks that are assigned to students in two courses: in Operational Investigation, where they are to create a virtual gallery of mathematical modeling problems, and in Discrete Mathematics, where they must create a virtual gallery of exercises on ordered sets and lattices. A quasi-experimental quantitative study has been developed. Details are provided on how the activities were structured, including the contribution of each student with problems of varying levels of difficulty and the detailed presentation of instructions on how to create and present the problems. The findings related to the problem gallery are presented, including critical incidents, an analysis of grades and student perception of the activity, highlighting the improved comprehension of concepts and skill development, as well as interaction among students during the activity. The results obtained are analyzed and it is concluded that the cooperative activities were effective for learning mathematics, emphasizing the importance of clear instructions, the equal contribution of students and the socialization of knowledge as key elements for the success of these initiatives.

Keywords – University mathematics, Operational research, Discrete mathematics, Student interaction, Mathematical modeling, Educational technology.

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1. Introduction

Traditionally, mathematics courses are recognized as generating the least enthusiasm among students, who often reject them as they consider them difficult and with no practical application in daily life, consistently pointing to their abstract nature. Certain challenges are present in the teaching of mathematics-related courses in a university setting. For Andrade-Molina, Montecino and Aguilar (2020), the different levels of preparation of the students complicate the instructional process. The abstractness of some mathematical concepts and the lack of practical examples generate comprehension problems for students and reduce their perception of its relevance. Furthermore, the traditional teaching methodology, focused on theoretical presentations and often limited by the lack of innovation and modern instructional resources, may not be effective for all students (Groenwald & Llinares, 2022; Aravena-Díaz, Díaz-Levicoy, Rodríguez-Alveal & Cárcamo-Mansilla, 2022). The perception of mathematics as a difficult subject discourages students, especially if they do not see a practical application in their field of study.

In courses like Operational Research and Discrete Mathematics, the instructional processes constitute a complex and diverse field in which there are few related studies. For Parra-Amaya and Velázquez-Rojas (2023), Carballo-Martínez (2014), Sánchez-Ansola, Acosta-Sánchez, Rosete-Suarez and Fernández-Oliva (2016) and Carranza-Carpio (2016), the teaching-learning processes for Discrete Mathematics face significant challenges due to the abstract and complex nature of its concepts, the variety of topics and the lack of innovative educational resources. Students often find it difficult to visualize and understand abstract theories: graphs, combinatorial analysis, ordered sets, groups and semi-groups. On the other hand, in Operational Research, the instructional process is *sui generis*. It involves not only the transmission of knowledge, but also the development of intellectual skills, creativity, talent and values, and it must also provide students with the skills they need to solve problems. Garriga-Garzón (2012) includes the need for practical methodologies for problem-solving. Garriga-Garzón (2015) and Jiménez-Lozano and Quesada-Ibargüen (2006), in tackling these problems, have developed resources such as problem-solving exercises that can help both students and professionals understand and apply linear programming concepts.

The problem described in these courses is complicated even further by the lack of consensus on the best teaching approach (Fracchia, Baeza & Martins, 2012). Traditional education, designed so that students hear certain contents, memorize them and later remember them to pass an exam, is no longer enough. For Pérez, Valenzuela-Castellanos, Díaz, González-Pienda and Núñez (2013) and Ladino-Calderón and Rincón-Infante (2022), traditional evaluation methods may not adequately reflect student comprehension, and feedback is usually insufficient or inappropriate. In addition, many courses unsuccessfully connect theoretical concepts to practical applications, which negatively affects student motivation.

To tackle these problems, it is essential to customize the learning, integrate educational technology, encourage cooperative learning, use active teaching methods and diversify evaluations (Nøhr, Hvid-Stenalt & Hagood, 2023; Campón-Cerro, Pasaco, López-Salas, Rodríguez-García & Di-Clemente, 2023). Studies in other areas of knowledge propose certain guidelines. Cuevas-Vallejo and Pluvinage (2013), for example, emphasize that the use of technology can boost learning results, while Pérez-Luna (2006) explores the potential of a new educational approach through the integration of teaching, training and research. Sánchez-Puentes (2010) considers the challenges and strategies for teaching research and Umbarila-Castiblanco (2015) discusses the use of research as a teaching strategy to improve learning.

As an active methodology, online cooperative learning facilitated by information and communications technologies promotes participation, interaction and the significance of the information for the students (Rivas & Espinoza, 2023). This approach is based on cooperative interaction, which is a fundamental social condition for learning (Suarez-Guerrero, 2003). Furthermore, the socialization and social learning process, which implies embracing rules and values, is crucial in the formation of identity and participation in society (León-Rubio, Cantero-Sánchez & Medina-Anzano, 1996).

The research conducted aims to explore and illustrate how the implementation of virtual problem galleries can support the teaching-learning process in courses perceived as difficult by university students, such as in the case of Operational Research and Discrete Mathematics. The intent is to show that if the students cooperatively build these galleries, this not only facilitates the comprehension of abstract mathematical concepts, it also fosters cooperative learning, interaction and the socialization of knowledge. In addition, the impact of this innovation on student motivation and the development of practical and cognitive skills is also evaluated.

2. Methodology

2.1. Type of Research and Approach

The research is quasi-experimental, since the experimental and control groups are not formed randomly. A constructivist perspective was adopted to apply the quantitative focus (Hernández-Sampieri & Mendoza, 2018). According to Vizcaíno-Zúñiga, Cedeño-Cedeño and Maldonado-Palacios (2023), research follows a quantitative approach when the variables analyzed to measure the effects of the intervention are numerical in nature.

2.2. Context

The study is carried out in the Professional School of Systems Engineering at San Agustín National University in Arequipa, Peru.

The experience consisting of creating a gallery of exercises on ordered sets and lattices was developed in the Discrete Mathematics course. According to the curriculum, this course is taught during the first academic semester.

The experience consisting of creating a gallery of mathematical modeling problems was carried out in the Operational Research course. This course was scheduled during the seventh semester of the curriculum.

2.3. Participants

The groups were formed and members were assigned at the discretion of the Professional School. These groups in particular were intentionally selected, as the researchers were in charge of the corresponding courses.

The experimental groups consisted of:

- Students registered in the Operational Research course, 37 of whom were registered in the 2022-A semester (group A) and 36 of whom were registered in the 2023-A semester (group A).
- Students registered in the Discrete Mathematics course, 40 of whom were registered in the 2021-A semester (group A) and 39 of whom were registered in the 2022-A semester (group A).

The control groups were made up of:

- The 38 students registered in the Operational Research course in the 2022-B semester (group B) and the 35 registered in the 2023-B semester (group B).
- The 38 students registered in the Discrete Mathematics course in the 2021-A semester (group B) and 38 students in the 2022-A semester (group B).

2.4. Intervention

The instructional intervention, the objective of which was the cooperative construction of a gallery of problems, combined cooperative learning techniques to implement a gallery of exercises/problems using the "glossary" tool of the Moodle platform.

2.5. Organization

A set of rules was designed for the joint creation of the glossary; these rules were made known to the experimental groups.

Following cooperative learning techniques, the students were grouped into base teams, on which they worked on the most complex activities throughout the course. For other activities, transitory groups were formed at random.

2.6. Inputs

Educational material in physical and digital format.

Resources and activities from the Moodle platform.

Tools from the Google suite.

Application software for solving mathematical models (WinQsb and Excel-solver).

Web search engines.

2.7. Data Collection and Analysis Techniques

To capture the perception of students regarding the activity, a questionnaire was administered that had 14 questions distributed across 4 dimensions. The responses were collected using a 5-point Likert-type scale.

The final grades earned by the students were collected from the institutional academic system.

In order to obtain a general idea of the behavior of the grades obtained by the students, descriptive measures were calculated for each group. The Shapiro-Wilks test was used to determine the normality of the grades. Since the grades did not follow a normal distribution, to compare the grades earned by the groups in each course, the Mann-Whitney test was used as a non-parametric alternative to the ANOVA. These tests were carried out with support from Excel.

3. The Experience

Virtual problem galleries are digital environments in which academic problems are collected and presented in a structured, accessible form (Oliveira-Dias, 2013); they serve a double function: as a learning resource and a platform for interaction. Every problem in the gallery usually includes its formulation, possible solutions and, in some cases, discussions or comments that enrich comprehension.

3.1. The Tool for the Implementation of the Virtual Gallery

The "Glossary" tool on the Moodle platform was used to implement the virtual problem galleries. This tool was chosen, bearing in mind that LMS institutional is the Moodle platform and the virtual classroom for two courses was already implemented on it.

In each case, work was done with two glossaries:

- The first was a transitional glossary in which the students recorded their proposals. This glossary was only accessible to the members of the base team.
- A second final glossary was made available to all the students. In this glossary, each student, having reviewed the comments received and improved their problems, delivered the final version of their proposal, for review and evaluation by the instructor.

3.2. The Task

Students registered in the Operational Research course were assigned the task of creating or gathering mathematical modeling problems.

Students registered in Discrete Mathematics were assigned the task of creating or gathering problems and exercises on ordered sets and lattices.

In both cases, it was indicated that the solution should be explained in detail, without leaving out any step or explanation, even when it might seem obvious.

3.3. The Instructions

The two experimental groups from Discrete Mathematics (2021-A, group A and 2022-A, group A) and in the first experimental group of Operational Research (2022-A, group A), were given guidelines on how to write and present the problems in the "Glossary" activity on the Moodle platform:

- In Discrete Mathematics, each student was required to contribute one exercise. In Operational Research, each student recorded two problems.
- The glossary entry was created using the first letter of the paternal surname.
- The title needed to be clear and concise and reflect the content of the problem.
- It began with a short paragraph that described the context of the problem and its relevance.
- The problem definition gave a detailed description of the problem or exercise to be solved and was required to contain all the information necessary to solve it.
- If necessary, data, assumptions or additional instructions were given to solve the problem.
- When recording a problem or exercise, it was necessary to check that it was not the same as any other that had already been registered.
- With regard to format, recommendations were made regarding the type font, size and spacing, ensuring that the notations and mathematical symbols were correctly used, including diagrams or figures when necessary, as well as how to reference the source of the problem if it had been taken from other material.

The second experimental group from Discrete Mathematics was instructed that each student must contribute two exercises.

- For the second experimental group from Operational Research (2023-A, group A), quality criteria were included:
- The definition of the problem needed to be clear and precise, avoiding any ambiguity.
- Each student was required to contribute at least two problems: one with an average level of difficulty (three or four variables, at least four restrictions) and one with a high level of difficulty (five or more variables and five or more restrictions).
- The problems were assessed according to their originality or creative adaptation, in the case of existing problems.
- The problem must have a possible solution. The solution, found with the support of specific software, was presented following the mathematical model.

3.4. Peer Review

Peer review was considered to be an effective strategy to improve the quality of the problems formulated by the students. As a result, it was requested for the problems or exercises created to be reviewed on the base teams.

A rubric was provided with clear assessment criteria: clarity of the definition, relevance of the problem, accuracy of the data and assumptions, format and originality.

Instructions were given regarding how to provide constructive feedback: specific comments, concrete suggestions for improvement and above all, being respectful and positive in the comments.

In light of the fact that the entire university community has Google email addresses and therefore has access to the Google suite, the review process was carried out using a document shared on Google Drive where the students were instructed to leave their feedback comments. This tool was used to store this document and the rubric for each problem. The base team was charged with creating a shared folder in Google Drive to which the instructor was also given access.

3.5. Scheduling of Activities

Deadlines were set for the students to submit their problems on the designated platform (they were given 2 weeks).

Ten days were allotted for the peer review.

Eight days were given for the preparation of the final version. During this time, the students were required to review the rubric and the detailed comments from their classmates in order to prepare the final version.

3.6. Hetero-Evaluation of the Activity

It was decided that the instructor would carry out the evaluation, both on an individual and a group level. Considered were the quality of the models or problems, the clarity of the solutions, and the feedback provided to classmates.

4. Results

To systematize the findings, four main aspects have been identified: the problem gallery, critical incidents, the analysis of the grades earned by the students and the perception of the students regarding the activity performed.

4.1. Achievements Related to the Problem Gallery

Table 1 shows the number of exercises uploaded to the exercise gallery for the Discrete Mathematics course. During the 2022-A semester, only 70 exercises were recorded, and there were four students who only presented one exercise.

For the Operational Research course, Table 2 shows the number of problems recorded in the problem gallery. In the 2022-A semester, only 64 problems were recorded, since four students only presented one problem. During the 2023-A semester a total of 65 problems were obtained, with 23 students creating the two requested problems, 5 students presenting 3 problems and 4 students only presenting one problem.

Students				No. of exercises recorded in the gallery
Semester	Registered	Participants	No. of participants	
2021-A	40	36	4	36
2022-A	39	37	2	70

Table 1. Number of exercises recorded in the Discrete Mathematics gallery

Students				No. of problems recorded in the gallery
Semester	Registered	Participants	No. of participants	
2022-A	37	34	3	64
2023-A	36	32	4	65

Table 2. Number of problems registered in the Operational Research gallery

4.2. Critical Incidents

In the second experimental group of Discrete Mathematics, when each student was asked to provide two exercises, several exercises were very similar to one another.

In the first experimental group of Operational Research, some problems were defined with two variables and could be solved using the graphing method.

In the second experimental group of Operational Research, when students were asked for at least two problems with different levels of difficulty, it was found that one entire base team presented three problems; one of them had a low level of difficulty, i.e., problems with two variables solved using the graphing method.

In both courses, there were students who did not do the activity, as reported by the base teams. Some exercises and/or problems were very similar to one another, with the only thing changing being the parameter values. Mistakes were also detected in the text, generally related to the agreement of number and person.

In both courses, when the problems from the first experience were reviewed and compared to those of the second experience, it was found that around 20% of the problems were repeated.

4.3. Analysis of the Grades Earned

Bearing in mind that normality of data is required for many statistical analyses, the first step was to analyze the behavior of the grades; a Shapiro-Wilks test was used for this purpose, to verify whether a data set follows a normal distribution, measuring how well the data correlate with a normal distribution.

Table 3 shows the calculated and theoretical values for each of the student groups, including both experimental and control groups. In cases where the calculated SW value is less than the theoretical SW value, the normality of the grades is rejected. The only case in which the grades follow a normal model is in the first experimental group of Operational Research.

Course	Sem.	Group type	Level of significance	Calculated SW pt	Theoretical SW	Decision
Discrete Mathematics	2021-A	Control	0.05	0.857	0.938	Normality is rejected
		Experimental	0.05	0.83	0.94	Normality is rejected
	2022-A	Control	0.05	0.877	0.938	Normality is rejected
		Experimental	0.05	0.899	0.938	Normality is rejected
Operational Research	2022-A	Control	0.05	0.881	0.938	Normality is rejected
		Experimental	0.05	0.969	0.935	**Normality is accepted**
	2023-A	Control	0.05	0.905	0.934	Normality is rejected
		Experimental	0.05	0.854	0.935	Normality is rejected

Table 3. Values and decisions related to the Shapiro-Wilks test

Since most of the grades did not fit a normal model, it was decided to include the value of the mean in the descriptive statistics. Table 4 shows some descriptive statistics of the grades earned by the students.

Course	Sem.	Group type	Size	Mean grade	Median grade	Standard deviation
Discrete Mathematics	2021-A	Control	38	12.18	12.5	2.01
		Experimental	40	13.73	13	2.41
	2022-A	Control	38	11.94	12	1.54
		Experimental	39	14.26	14.5	2.4
Operational Research	2022-A	Control	38	11.92	12.5	2.77
		Experimental	37	13.14	13	2.76
	2023-A	Control	35	11.88	12	2.9
		Experimental	36	13.39	14	2.08

Table 4. Descriptive statistics of the grades on a vigesimal scale

The percentage of passing and failing students was also analyzed in each group of students. Figure 1 details this information in the case of the Discrete Mathematics course, while Figure 2 shows this for the Operational Research course.

To establish whether the differences found were statistically significant, the Mann-Whitney U test was used; this test is useful when you wish to compare two sample means that come from the same population. A two-tailed test was used with a level of significance of 0.05.

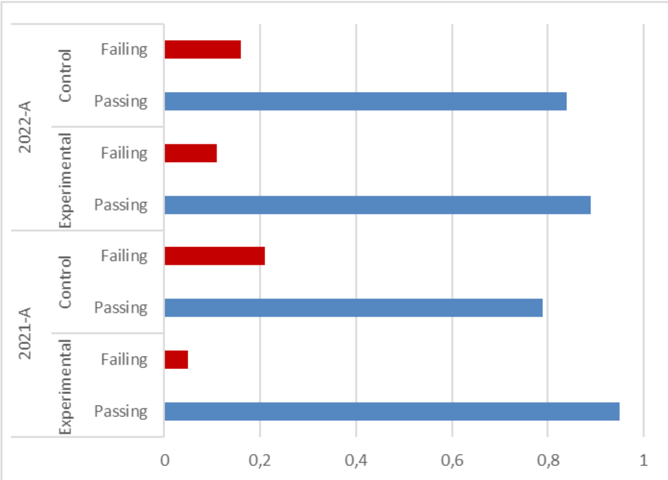

Figure 1. Percent of students passing and failing Discrete Mathematics

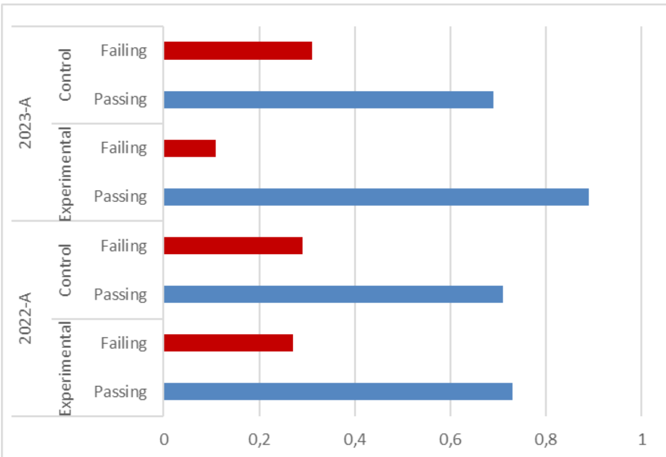

Figure 2. Percent of students passing and failing Operational Research

Table 5 shows the values required for the applications of the Mann-Whitney U test and the decision made in the Discrete Mathematics course. Table 6 presents the same information for the case of the Operational Research course.

		2021-A			**2022-A**	
		calculated z	**critical z**		**calculated z**	**critical z**
U1	1012.5	2.53	1.96	1177	4.44	1.96
U2	507.5	-2.53	-1.96	305	-4.44	-1.96
Decision	It is agreed that the behavior is different.			It is agreed that the behavior is different.		

Table 5. Values and decision for the Mann-Whitney U test in Discrete Mathematics

		2022-A			2023-A	
		calculated z	**critical z**		**calculated z**	**critical z**
U1	846	1.99	1.96	861	2.66	1.96
U2	486	-1.99	-1.96	399	-2.66	-1.96
Decision	It is agreed that the behavior is different.			It is agreed that the behavior is different.		

Table 6. Values and decision for the Mann-Whitney U test in Operational Research

4.4. Student Perception Regarding the Activity Performed

At the end of the activity, a survey was administered to the second experimental group of Operational Research. The objective was to obtain an overview of how the students perceived the virtual problem gallery activity.

A questionnaire was constructed that was implemented in the virtual classroom (part of Moodle), using the "Survey" activity. The questionnaire was validated according to the judgment of experts, according to the procedure described by Cabero and Llorentes (2015); three experts were used for this process. These three experts were identified according to their academic and professional profiles, and the coefficient of expert competencies was calculated for each of them.

The questionnaire included 14 questions, which were organized into four dimensions: (1) Overall activity rating, (2) Specific aspects of the activity, (3) Interaction among students and (4) Socialization of the knowledge. The responses were collected using a 5-point Likert scale with values from 1 to 5, where 1 represents the lowest value on the scale and 5 the highest.

	Overall activity rating	**1**	**2**	**3**	**4**	**5**	**μ**
P01	How satisfied are you with the glossary creation activity?	2.5	5	7.5	27.5	57.5	4.32
	Specific aspects of the activity:	**1**	**2**	**3**	**4**	**5**	**μ**
P02	How useful did you find the activity for improving your understanding of the terms?	0	0	7.5	30	62.5	4.55
P03	Have you improved or developed skills through this activity? (e.g., critical thinking, cooperation, problem-solving)	2.5	2.5	12.5	32.5	50	4.25
P04	How clear were the instructions provided to perform the activity?	5	7.5	12.5	32.5	42.5	4
P05	Was this activity motivating for you?	0	0	0.15	0.45	0.4	4.22
P06	Do you think that evaluating your classmates' work improved your mastery of the topic?	0	5	15	42.5	37.5	4.12
	Interaction among students:	**1**	**2**	**3**	**4**	**5**	**μ**
P07	How effective was the interaction among students during the creation of the glossary?	5	7.5	12.5	37.5	37.5	3.95
P08	How comfortable were you when working with other students on this activity?	7.5	10	22.5	37.5	22.5	3.58
P09	Do you feel like all the members of the group contributed equally to the creation of the glossary?	5	7.5	30	35	22.5	3.62
P10	How accessible were your classmates to discuss and solve any doubts during the activity?	7.5	10	22.5	37.5	22.5	3.58
	Socialization of the knowledge	**1**	**2**	**3**	**4**	**5**	**μ**
P11	How useful was the activity for sharing and socializing the knowledge acquired with your classmates?	0	2.5	12.5	45	40	4.22
P12	Do you feel that the activity helped improve the collective skills of the group regarding the mathematical modeling of problems?	0	0	22.5	37.5	45	4.42
P13	How efficient was the platform used for cooperation and the socialization of the glossary?	2.5	2.5	22.5	35	37.5	4.02
P14	Do you feel that the activity promoted a cooperative learning environment?	2.5	7.5	27.5	40	22.5	3.72

Table 7. Percentages of responses in each category of questions on the questionnaire applied to the students

Table 7 shows the percentages of students who marked each level of the scale and the mean score obtained for each question on the questionnaire.

Figure 3 shows the mean scores obtained for each question on the questionnaire. It can be seen that all of them exceed the mean score of the scale (red line). The lowest scores were obtained on questions 07, 08 and 10, while the highest were for questions 02 and 12.

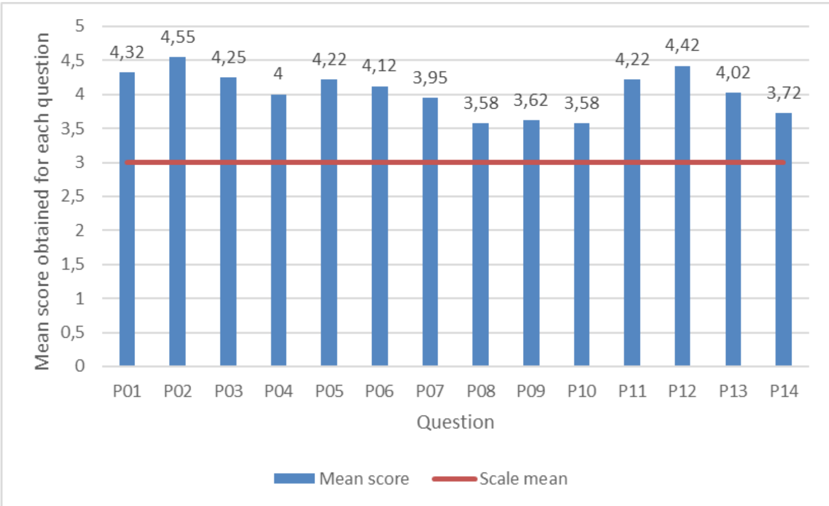

Figure 3. Behavior of the mean scores obtained for each question on the questionnaire

5. Discussion

This study agrees with the findings of Peralta-Hernández and Tirado-Segura (2023) in the sense that it is not enough to use digital tools that facilitate interaction among students and the socialization of knowledge; it is important for the educational design to foster and establish the conditions necessary for the effective use of these tools. This instructional intervention used cooperative learning techniques guided by the instructor, which contrasts with collaborative learning in which the students act autonomously. This focus made it possible to ensure proper management and continuous support during the learning process. This is evidenced by the results obtained in the Operational Research course. In it, having included active and practical methodologies in the instructional process meant not only the transfer of knowledge, but also the development of intellectual skills and problem-solving capacity (Garriga-Garzón, 2012).

Villalonga-Pons, Besalú, Samà-Camí and Sancho-Vinuesa (2023) state that each educational institution is unique and the implementation of instructional activities depends on their characteristics and the resources available to them. It is for this reason that the university's Moodle platform and the tools provided by G-Suite for Education were used to implement the virtual problem and exercise galleries.

The cooperative creation of virtual problem and exercise galleries, facilitated by various technological tools, has increased student participation (Rivas & Espinoza, 2023); this circumstance is reflected in the number of problems and exercises registered in the galleries of each course. Furthermore, the interactions generated established the social conditions necessary for learning (Suarez-Guerrero, 2003) and promoted teamwork and cooperation skills. However, educational interventions such as those described in this article, based on online cooperative learning, can face challenges such as cultural identity and the digital gap (Estrada de León, García-Treviño & Medellín-Rodríguez, 2020).

The review of the problems and the incorporation of comments made on the base teams promoted a cooperative learning environment and improved the quality of the work and the comprehension of the problems that were formulated (Alpaca, 2018). This process also promoted critical evaluation and reflection skills. By using documents shared on Google Drive, it was possible to track the comments and identify what each participant had commented.

Andrade-Molina et al. (2020) propose that the levels of preparation and maturity of the students have an influence on the instructional processes; this is the root of some of the critical incidents that occurred as listed in the results section.

Binali, Tsai and Chang (2021) state that the students' real practice should be analyzed, in other words, their real involvement in the activities proposed in a course. This explains why there was a lower level of achievement in Discrete Mathematics than in Operational Research. The first course corresponds to the first semester in the curriculum and the second to the seventh semester. However, transitioning from an instructor-focused teaching methodology to one focused on students increased motivation and improved learning results on behalf of the students. This confirms the positions of Groenwald and Llinares (2022) and Aravena-Díaz et al. (2022) in the sense that the traditional teaching methodology, focused on theoretical exposition, cannot be effective for all students.

This coincides with studies by Koehler, Mishra and Cain (2015), Niess (2015), Chura-Quispe, García-Castro, Limache-Arocutipa and de la Cruz (2024) and Bedregal-Alpaca, Tupacyupanqui-Jaén and Cornejo-Aparicio (2020) who collectively point to the integration of technology, contents and pedagogy as creating an ecosystem in which the instructor takes on the role of techno-educator in order to propose solutions to certain educational challenges. One of them is to prevent students from being discouraged by the belief that mathematics is a difficult subject.

The statistical analysis of the learning results reveals a significant improvement after the implementation of the cooperative activities and the use of the virtual problem and exercise galleries. The results of the Mann-Whitney U test confirm significant improvement in the grades earned by students in both Operational Research and Discrete Mathematics.

The application of a questionnaire to evaluate student perception of the activity carried out revealed that most considered that the technology was effective in encouraging debate, cooperation and interaction (Dabbagh, Fake & Zhang, 2019; Bedregal-Alpaca, Sharhorodska, Tupacyupanqui-Jaén & Corneko-Aparicio, 2020).

Having used a 14-item questionnaire grouped into four dimensions, in addition to organizing the questionnaire, facilitated the student responses and data analysis. It was possible to compare the perception among the different dimensions, resulting in the "Student interaction" dimension receiving the lowest scores. This could be explained by the analysis performed by León-Rubio et al. (1996), who argue that the socialization and social learning process —which includes the internalization of norms and values— is fundamental for the formation of identity and participation in society. The low rating for the interaction could indicate that the students need more opportunities to interact in a significant manner. Factors such as the lack of cohesion, interpersonal conflicts or the unequal distribution of work could have negatively affected the interaction, which would lead to redefining the roles within the base teams.

The higher scores on the "Specific aspects of the activity" and "Socialization of knowledge" indicate that the students appreciated the structure and content of the activity, and that they positively valued the opportunity to share their own knowledge and experiences.

All three of these dimensions —"Specific aspects of the activity", "Interaction among students" and "Socialization of knowledge"— have a significant influence on the overall perception of the activity. The quality of the interaction among the students could have influenced their satisfaction with the activity. The high score obtained on the dimensions "Specific aspects of the activity" and "Socialization of knowledge" implies that the students perceived a positive impact on their learning and comprehension, which is corroborated by the statistical analysis of the grades earned by the students. In the 2023-A semester, the statistics that describe the behavior of the grades earned in the experimental group are significantly better than those obtained in the control group.

6. Conclusions

For the cooperative activities to constitute useful tools for active learning and developing key competences in students, their design must have a comprehensive focus. This implies establishing clear objectives, defining an appropriate structure, using effective technological tools, providing the right support from the instructor and carrying out a reflective evaluation of the actions.

The results suggest that the creation of mathematical problem galleries not only improves the learning of specific aspects of Operational Research and Discrete Mathematics, it also develops important skills and fosters a cooperative learning environment, which responds to the objective of showing how these galleries strengthen the teaching-learning processes in complex subjects.

Student interaction through the Moodle platform is important for the cooperative construction of knowledge. This endorses the fact that the activity facilitates the comprehension of mathematical concepts and encourages the socialization of knowledge.

The cooperative implementation of the virtual problem and exercise galleries had a positive impact on the students' learning results. The statistical analysis of the results obtained validates the adoption of new educational approaches that focus on the teaching-learning processes in the student.

The construction of virtual problem and exercise galleries evidenced the effectiveness of cooperative learning and its impact on the socialization of knowledge. However, it also evidenced the need to improve the strategies for supporting a more effective and satisfying interaction among the students.

The results obtained reinforce the importance of continuing to explore and use educational technology to improve the quality of higher education. This meets the objective of assessing the impact of this innovation.

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References

Alpaca, N.B. (2018). Cooperative learning using Moodle as a support resource: Proposal for continuous evaluation in operational research. In *36th International Conference of the Chilean Computer Science Society (SCCC)* (1-9). Arica, Chile. https://doi.org/10.1109/SCCC.2017.8405131

Andrade-Molina, M., Montecino, A., & Aguilar, M.S. (2020). Beyond quality metrics: defying journal rankings as the philosopher's stone of mathematics education research. *Educational Studies in Mathematics,* 103 (3), 359-374. https://doi.org/10.1007/s10649-020-09932-9

Aravena-Díaz, M., Díaz-Levicoy, D., Rodríguez-Alveal, F., & Cárcamo-Mansilla, N. (2022). Estudio de caso y modelado matemático en la formación de ingenieros. Caracterización de habilidades STEM. *Ingeniare. Revista Chilena de Ingeniería,* 30(1), 37-56. https://doi.org/10.4067/S0718-33052022000100037

Bedregal-Alpaca, N., Sharhorodska, O., Tupacyupanqui-Jaén, D., & Corneko-Aparicio, V. (2020). Problem based Learning with Information and Communications Technology Support: An Experience in the Teaching-Learning of Matrix Algebra. *International Journal of Advanced Computer Science and Applications,* 11. https://doi.org/10.14569/IJACSA.2020.0110315

Bedregal-Alpaca, N., Tupacyupanqui-Jaén, D., & Cornejo-Aparicio, V. (2020). Análisis del rendimiento académico de los estudiantes de Ingeniería de Sistemas, posibilidades de deserción y propuestas para su retención. *Ingeniare. Revista Chilena de Ingeniería,* 28(4), 668-683. https://doi.org/10.4067/S0718-33052020000400668

Binali, T., Tsai, C., & Chang, H. (2021). University students' profiles of online learning and their relation to online metacognitive regulation and internet-specific epistemic justification. *Computers & Education,* 175. https://doi.org/10.1016/j.compedu.2021.104315

Cabero, J., & Llorentes, M.C. (2015). Entornos Personales de Aprendizaje (PLE): Valoración Educativa a través de Expertos. *Areté.* 1(1), 7-19.

Campón-Cerro, A., Pasaco, B., López-Salas, S., Rodríguez-García, J., & Di-Clemente, E. (2023). Seguimiento y evaluación virtual de la enseñanza universitaria: percepción del alumnado de las titulaciones de empresa en la Universidad de Extremadura. *Revista de Investigación en Educación,* 21. 278-294. https://doi.org/10.35869/reined.v21i2.4604

Carballo-Martínez, Y. (2014). *Sistema de Objetos de Aprendizaje Interactivos y Experimentales para la Matemática Discreta.* Ciudad de La Habana, Cuba: Universidad de las Ciencias Informáticas.

Carranza-Carpio, G. (2016). Entrenamiento en la solución de problemas de matemática discreta. Impacto social. *Revista Universidad y Sociedad,* 8(1), 130-139.

Chura-Quispe, G., García-Castro, R.A., Limache-Arocutipa, G.P., & de la Cruz, B.D.L. (2024). Creation and validation of a techno pedagogical design with flipped learning and collaborative writing. *RIED-Revista Iberoamericana de Educación a Distancia,* 27(2). https://doi.org/10.5944/ried.27.2.38995

Cuevas-Vallejo, C., & Pluvinage F., (2013). Investigaciones sobre la enseñanza del cálculo. *El Cálculo y su Enseñanza,* 4(1), 47-64. https://doi.org/10.61174/recacym.v4i1.156

Dabbagh, N., Fake, H., & Zhang, Z. (2019). Perspectivas de los estudiantes sobre el uso de la tecnología para el aprendizaje en la educación superior. *RIED-Revista Iberoamericana de Educación a Distancia,* 22(1), 127-152. Available at: https://revistas.uned.es/index.php/ried/article/view/22102

Estrada de León, A., García-Treviño, M., & Medellín-Rodríguez, E. (2020). Interacciones de estudiantes en línea, retrospectiva de una década. *Revista Electrónica Sobre Tecnología, Educación y Sociedad,* 7(14), 187-202.

Fracchia, C.C., Baeza, N.M., & Martins, A. (2012). ECDIA: entorno colaborativo para el diseño e implementación de algoritmos. In *XVIII Congreso Argentino de Ciencias de la Computación.*

Garriga-Garzón, F. (2012). *Problemas resueltos de programación lineal.* OmniaScience. https://doi.org/10.3926/oss.7

Garriga-Garzón, F. (2015). El apasionante mundo de la programación lineal. OmniaScience. https://doi.org/10.3926/oss.19

Groenwald, C.L.O., & Llinares, S. (2022). Aprendiendo a mirar profesionalmente las situaciones de enseñanza de las matemáticas. *Revista Venezolana de Investigación en Educación Matemática,* 2(2), 1-26. https://doi.org/10.54541/reviem.v2i2.29

Hernández-Sampieri, R., & Mendoza C. (2018). *Metodología de la investigación. Las rutas cuantitativa, cualitativa y mixta.* Ciudad de México, México: Editorial Mc Graw Hill Education. https://doi.org/10.22201/fesc.20072236e.2019.10.18.6

Jiménez-Lozano, G., & Quesada-Ibargüen, V. (2006). *Cien problemas de programación lineal.* Universidad Nacional de Colombia - Sede Manizales.

Koehler, M.J., Mishra, P., & Cain, W. (2015). ¿Qué son los Saberes Tecnológicos y Pedagógicos del Contenido (TPACK)? *Virtualidad, Educación y Ciencia,* 6(10), 9-23. https://doi.org/10.60020/1853-6530.v6.n10.11552

Ladino-Calderón, F., & Rincón-Infante, S. (2022). Aprendizaje estratégico en la modalidad distancia tradicional: Caracterización de la enseñanza-aprendizaje. *Revista Electrónica Educare,* 26(1), 180-195. https://doi.org/10.15359/ree.26-1.10

León-Rubio, J.M., Cantero-Sánchez, F.J., & Medina-Anzano, S. (1996). Socialización y aprendizaje social. In León-Rubio, J.M. (Ed.), *Psicología social: una guía para el estudio* (51-66). Sevilla: Kronos.

Niess, M.L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education,* 21(5), 509-523. https://doi.org/10.1016/j.tate.2005.03.006

Nøhr, L., Hvid-Stenalt, M., & Hagood, D. (2023). La agencia de los profesores universitarios en relación con el uso de la tecnología en la enseñanza: una investigación cuantitativa. *Edutec. Revista Electrónica de Tecnología Educativa,* (86), 40-61. https://doi.org/10.21556/edutec.2023.86.2915

Oliveira-Dias, S.R. (2013). El Glosario como Propuesta Didáctica en el aprendizaje de léxico. *Revista Nebrija de Lingüística Aplicada a la Enseñanza de Lenguas,* 13.

Parra-Amaya, M., & Velázquez-Rojas, J. (2023). Matemática discreta en aulas multigrado de primaria. In *XVI CIAEM-IACME Conferencia Interamericana de Educación Matemática.* Lima, Perú.

Peralta-Hernández, J., & Tirado-Segura, F. (2023). Diseño de un entorno virtual de aprendizaje para promover la creatividad colaborativa en universitarios. *RIED-Revista Iberoamericana de Educación a Distancia,* 26(2), 175-197. https://doi.org/10.5944/ried.26.2.36209

Pérez-Luna, E. (2006). Enseñanza, formación e investigación: un lugar para el otro en la pedagogía por-venir. *Revista de Teoría y Didáctica de las Ciencias Sociales,* 11, 95-112.

Pérez, M.V., Valenzuela-Castellanos, M., Díaz, M,A., González-Pienda, J., & Núñez, J. (2013). Dificultades de aprendizaje en estudiantes universitarios de primer año. *Atenea (Concepción),* 508, 135-150. https://doi.org/10.4067/S0718-04622013000200010

Rivas, J., & Espinoza, A. (2023). Desarrollo de un proyecto de aprendizaje colaborativo en línea. El trabajo colaborativo y las Tecnologías de Información y Comunicación. La Perspectiva de la Internacionalización. *Revista de Educación y Derecho,* (28). https://doi.org/10.1344/REYD2023.28.42805

Sánchez-Ansola, E., Acosta-Sánchez, R., Rosete-Suarez, A., & Fernández-Oliva, P. (2016). Lecciones aprendidas en la impartición de la asignatura Matemáticas Discretas. *Revista Iberoamericana de Tecnología en Educación y Educación en Tecnología,* 17, 30-37.

Sánchez-Puentes, R. (2010). *Enseñar a investigar. Una didáctica nueva de la investigación en ciencias sociales y humanas.* Universidad Nacional Autónoma de México.

Suárez-Guerrero, C. (2003). La interacción cooperativa: condición social de aprendizaje. *Educación,* 12(23), 79-100. https://doi.org/10.18800/educacion.200302.004

Umbarila-Castiblanco, X. (2015). *Sobre la enseñanza y el aprendizaje por investigación.* Universidad Santo Tomás Villavicencio.

Villalonga-Pons, J., Besalú, M., Samà-Camí, A., & Sancho-Vinuesa, T. (2023). Estrategias de aprendizaje de estudiantes de Ingeniería en línea. *RIED-Revista Iberoamericana de Educación a Distancia,* 26(2), 237-256. https://doi.org/10.5944/ried.26.2.36257

Vizcaíno-Zúñiga, P., Cedeño-Cedeño, R., & Maldonado-Palacios, I. (2023). Metodología de la investigación científica: guía práctica. *Ciencia Latina Revista Científica Multidisciplinar,* 7(4), 9723-9762. https://doi.org/10.37811/cl_rcm.v7i4.7658

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