ADVANCES IN BUILDING EDUCATION
INNOVACIÓN EDUCATIVA EN EDIFICACIÓN

Project-Based Learning and Self-Evaluation for Training Industrial Engineers in Graphic Expression

Aprendizaje Basado en Proyectos y Autoevaluación para estudiantes de Expresión Gráfica de Grado en Ingeniería en Organización Industrial

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HIGHLIGHTS

- Allowing students with practical competences in technical drawing
  Adquisición de competencias prácticas en dibujo técnico
- Nurturing creativity and practical skills through project-based learning in graphic expression
  Fomento la creatividad a través del aprendizaje basado en proyectos

- Student Perceptions: Project-Based Learning in Engineering Education
  Percepción de los estudiantes de la metodología Aprendizaje Basado en Proyectos
- Innovative Assessment: Peer Evaluation in Graphic Expression
  Evaluación Innovadora: Evaluación por pares en Expresión Gráfica
- Enhancing learning outcomes through collaborative evaluation and self-assessment.
  Mejorando resultados de aprendizaje a través de evaluaciones colaborativas

RESUMEN

Este trabajo describe la metodología de aprendizaje basado en proyectos implementada en el curso de expresión gráfica dentro del programa de grado en ingeniería de organización industrial. El objetivo principal era dotar a los estudiantes de primer año de ingeniería con habilidades en expresión gráfica y gestión de diseño asistido por ordenador (CAD), abarcando la visión espacial, el manejo de software, el dibujo técnico y la interpretación de planos y diagramas. La percepción de los estudiantes sobre este enfoque de aprendizaje activo fue positiva, ya que no solo facilitó la adquisición de competencias transversales como "gestión de la información" y "trabajo en equipo", sino que también profundizó en la gestión del software CAD. La oportunidad de evaluación entre compañeros y autoevaluación resultó en un dominio mejorado de habilidades específicas, afirmando que este método integrado de enseñanza y evaluación fortaleció la percepción de los estudiantes sobre su competencia en expresión gráfica. La participación activa de los estudiantes en la evaluación de su propio trabajo y el de sus compañeros fomentó una comprensión más profunda de la materia y estimuló el aprendizaje colaborativo. Como resultado, los estudiantes salieron del curso con un mayor sentido de confianza en sus habilidades y una mayor apreciación de las aplicaciones prácticas de sus nuevas habilidades en el campo de la ingeniería.

Palabras clave: *Diseño Asistido por Ordenador, CAD, trabajo en grupo*

ABSTRACT

This work outlines the project-based learning methodology implemented in the graphic expression course within the industrial organization engineering degree program. The primary aim was to equip first-year engineering students with skills in graphic expression and computer-aided design (CAD) management, encompassing spatial vision, software handling, technical drawing, and interpretation of plans and diagrams. Students' perception of this active learning approach was positive, as it not only facilitated the acquisition of cross-cutting competencies like "information management" and "teamwork" but also delved into CAD software management. The opportunity for peer evaluation and self-assessment resulted in enhanced mastery of specific skills, affirming that this integrated teaching and evaluation method bolstered students' perception of their proficiency in graphic expression. The active involvement of students in evaluating their own work and that of their peers fostered a deeper understanding of the subject matter and encouraged collaborative learning. Consequently, students emerged from the course with a heightened sense of confidence in their abilities and a greater appreciation for the practical applications of their newfound skills in the field of engineering.

Keywords: *Computer-Aided Design, CAD, working group.*

1. INTRODUCTION

Graphic Expression is a basic subject in the degrees of architecture and engineering areas that is taught in the first year of many technical degrees. This subject focuses on the acquisition of basic knowledge of computer tools related to Computer Aided Design that allow the realization of perspective representations, as well as block, flow and pipe diagrams and implementation plans.

The planning of the subject included in the register of universities establishes that the teaching methodologies correspond to attendance at lectures (MD-1), solving exercises (MD-2), and carrying out practical activities (MD-7). On the other hand, the evaluation system consists of both exams (SE-1) and evaluation of practices (SE-5), making it very difficult to apply industrial concepts until the last sessions.

The general objective of the course is for the student to acquire the basic knowledge of industrial drawing (international norms of technical expression, representations and perspectives, block diagrams, flow and pipes, implementation plans, etc.) as well as the management of computer design tools (CAD). This subject is important within the Industrial Engineering degree as it allows the student to carry out the representations of equipment and processes related to said degree, which has a markedly technical and applied profile.

Students who take this subject must acquire the following specific competence:

> *"Know and master the main techniques of graphic expression and computer-aided design and have the ability to apply them in the representation of parts and objects and in the preparation of engineering plans."*

Expected learning outcomes for students who take the course will be:

1. Define the elements that make up an industrial plan, including the title and revision block.

2. Build drawings of objects and geometric Fig.s using conventional and assisted tools.

3. Construct drawings in two and three dimensions to express and interpret views and sections of parts, and orthographic projections of parts using combined drawings of three views.

4. Apply drawing standardization in engineering, including the use of conventions to represent symbols, types and weight of lines, and size of objects.

5. Apply the principles of dimensioning and relate the dimensions of one view with those of another.

6. Use computer-aided design programs to draw two-dimensional geometries and three-dimensional solid models that represent parts or installations.

7. Use computer-aided design programs to produce plans for engineering projects.

Traditional learning of graphic expression is still carried out but most of the *curriculum* intensifies the use of computer programs for teaching it [1]. Also, computer aided design (CAD) is usually learned in CAD laboratories where the lecturers act as a guide in the learning-teaching process rather than merely using an expositive method [2]. It is noteworthy that CAD software is

extensively used in the industrial environment, so that skill in the management of these tools would be an advantage for integration in the labour market (Glassey et al., 2013). These considerations demonstrate that in this subject is very important to connect basic knowledge and the professional environment.

There is a growing concern on the part of university professors to train engineers with the skills required by the work environment, and for this reason new methodologies are being applied, among which is Project-Based Learning (PBL), in which students, organized by groups, acquire, use, and apply the concepts of the subject to solve a project.

Already in 2003, six reasons why most engineering education programs are deficient in address the concerns of modern society [3]:

• Most engineering curricula are focused on engineering sciences and technical courses, leaving aside their practical integration.

• Current programs do not provide enough design experience to students.

• Graduates lack communication skills and teamwork experience.

• Programs need to develop more awareness among students of social, environmental, economic and legal issues.

• Teachers have no practical experience.

• Teaching strategies should be more student-centered.

Engineering programs have searched for ways to solve these problems, and project-based learning can be presented as an alternative. In PBL, five learning moments can be identified [4, 5]:

a. Students begin with a driving question. This part is related to the problem to be solved.

b. Once the problem has been identified, students brainstorm ideas based on concepts from the discipline.

c. Possible solutions are discussed, involving collaborative activities, in contrast to the expert problem solving of traditional learning methodologies.

d. While the discussion is taking place, students deepen their knowledge by participating in activities that are normally beyond their capacity, and

e. Students finish with a design that address the main question.

This methodology is being implemented in teaching in the field of engineering [6], since it allows an approach to reality, and allows students to take responsibility for their own learning, developing skills for personal relationships, working on critical evaluation and increasing the motivation of their students by presenting real problems [7]. The most important features appear in Fig. 1.

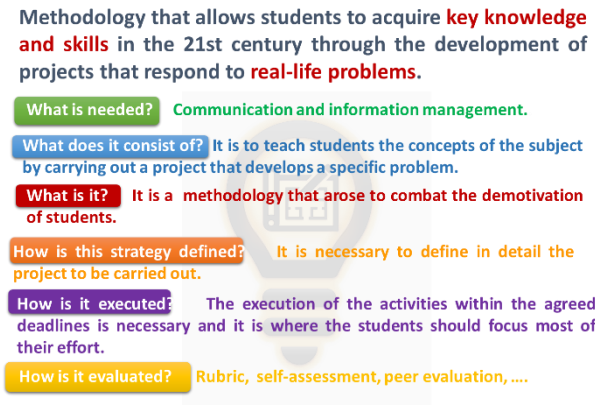

Fig. 1: *Definition and characteristics of PROJECT-BASED LEARNING. Source: [8]*

In this work, an experience with this methodology is analyzed, that consists of carrying out a project in a certain time, students must solve a problem or tackle a task by planning, designing and carrying out a series of activities, applying the acquired learning and the use of effective resources. It encompasses the entire thought process, beginning with the effort from the initial idea to the solution of the problem. [9, 10]. Students become protagonists of their own learning and develop their autonomy and responsibility because they are in charge of planning, structuring the work and preparing the product to resolve the question raised, as well as qualifying [11] .

2. MATERIALS AND METHODS

2.1 Participants

The subject in which this methodology is carried out is Graphic Expression, taken during the second quarter of the first academic year in the degree of Engineering in Industrial Organization and in the double degree of Science, Management and Engineering of Services - Engineering in Industrial Organization. The collection of information has been carried out during the 2020-21 academic years. The student group was 56 students.

2.2 PBL methodology

The Guide for the Verification and Modification of the Official Titles of Bachelor's and Master's degrees, from the Madri+d Foundation for Knowledge, recently published (July 2022; [12]) defines the Project Oriented or Based on Learning methodology Projects (ABP) or Learning by Projects or Project Based Learning (PBL) as follows:

> "*Students carry out a project (or several) in a certain time. Projects could be oriented towards the creation of a final product, the elaboration of content, the design of a professional intervention program or the resolution of a problem. It will be necessary use an adequate process of analysis and collection of information, plan the procedures, strategies and necessary resources, for the design and elaboration of the product etc. In this process, students must apply the knowledge, skills and acquired competencies and use appropriate or available resources. The teacher acts as supervisor and adviser of student work. These projects can be done in groups or individually.*"

The steps followed for the implementation of an activity in Learning by Projects are the following:

A) Start

At the beginning of the classes the introduction of the subject was made, explaining the Teaching Guide of the same, framing the subject within the degree, explaining the competences to be developed, the syllabi, the teaching methodology to be followed and the evaluation system to be used. It was commented that the subject was going to be divided into different parts. On the one hand, the acquisition of CAD knowledge would be evaluated by carrying out mandatory and individual weekly practices in the computer room, gradually increasing their difficulty [13]. On the other hand, a final exam of the subject would be carried out where all the earning results of this subject would be evaluated, and for this, this test would consist of both a theoretical part and a practical part, carrying out both activities individually. But what is remarkable about this subject is that there is a part of qualification that would consist of carrying out teamwork during the course, which will be defended at the end of the semester, in which cooperative learning strategies will be used. Therefore, a great emphasis was placed on the possibility of generating work teams, having sufficient time to do so.

At this stage, the topics to be discussed have been defined, and partial goals and evaluation methods are established. The resources and prerequisites and objectives of the project have been identified.

B) Initial activities of the teams

At this stage, a preliminary planning is carried out. Knowledge on the subject is shared and possible projects for the team. The level and depth of the project has been established with a possible work plan that divides the project into subtasks.

The guidelines given to students are as follows:

> "*There will be a seminar that will consist of group work with a brief presentation of it. For this, the class will be divided into groups of 4 people and different designs will be proposed that they will have to make using what they have learned in the theoretical and practical classes of the Graphic Expression subject. The design will be a plan structured by layers and will include:*
>
> - *A2 title blocks that collects the necessary information in a standardized format.*
> - *View dimensioning with front, lateral and top view of the building.*
> - *Descriptive plan.*
> - *Basic air conditioning installation.*
> - *Electrical installation.*
> - *Water installation.*
>
> *Additionally, four 3D models of basic elements that can be found in these facilities will be made."*

Once the students know what the work consists of, different topics have been prepared for the groups to work on independently. Different topics are summarized below:

- DESIGN OF A SCHOOL:

It must contain six classrooms, a dining room (with kitchen), a gym (with changing rooms), two offices, a meeting room, a concierge room and a patio, all arranged on 2 floors with 2 toilets / floor.

- DESIGN OF A MECHANICAL WORKSHOP

It must contain two milling machines (1 vertical and 1 horizontal), a parallel lathe, two CNC machining centers, a press, a shearing machine and a column drill and a warehouse, separated by bars from the rest of the building.

- DESIGN OF A SHOPPING MALL

It should contain six shops, two restaurants (with kitchens), a playground, a bank (with an ATM) and parking for 30 cars, all arranged on 2 floors with 2 toilets/floor.

- DESIGN OF A HOTEL

It must contain three double rooms, two single rooms and one suite, all with individual bathrooms, a restaurant, a reception, an office, a gym (with changing room and sauna) and a small solarium, all arranged on 2 floors with of 1 toilet / floor.

- DESIGN OF A LOGISTICS CENTER

It must contain an office with two offices and a meeting room, a toilet, a dining room for staff, and a store. The entire ship must be crossed by a crane bridge and have merchandise entry and exit on opposite walls. Space for 3 trucks working simultaneously and parking for 10 cars must be considered.

C. Project implementation

Students must complete the tasks and partial goals one by one. Work plan should divide the project into a sequence of tasks, each with its own schedule and goal. Team members take part in collaborative learning and solution problem cooperative.

It is necessary to keep track of the subject, since reference is made, very often, to the application of the concepts exposed in the theoretical sessions in the realization of the final team. Two intermediate sessions were planned in which a control would be carried out, giving the student specific feedback about their strengths and areas of opportunity, in such a way that they can take advantage of possibilities and rectify the path.

D) Progress towards completion.

The final result of a project is a piece of work that includes what was initially exposed and a presentation addressed to the classmates themselves. In our classroom, group presentations are an integral part of the learning

experience, with attendance mandatory for all students. These presentations serve as a platform for each group to showcase their projects comprehensively. During these sessions, students are required to articulate all facets of their work, providing insight into the challenges encountered and the strategies employed to overcome them. Each group is expected to address every aspect of their project, from inception to execution, elucidating the intricacies of their approach and the methodologies utilized. Moreover, these presentations offer an opportunity for students to engage in critical reflection, discussing not only their successes but also the obstacles they encountered throughout the process. By sharing their experiences and insights with their peers, students not only deepen their understanding of the subject matter but also cultivate essential communication and presentation skills. Thus, these classroom presentations foster a collaborative learning environment where students can learn from one another's experiences and perspectives, enriching their educational journey.

2.3 Evaluation of the activity

There will be both a self-evaluation and a mutual evaluation between the members of the equipment. The teacher also evaluates. The evaluation of this group work would be carried out according to the quality of the work, but this evaluation will be carried out by the teachers of the subject, as well as by the rest of the groups and by the own qualification that each group considers that it must achieve with that job. In Fig. 2 the distribution of the evaluations are shown:

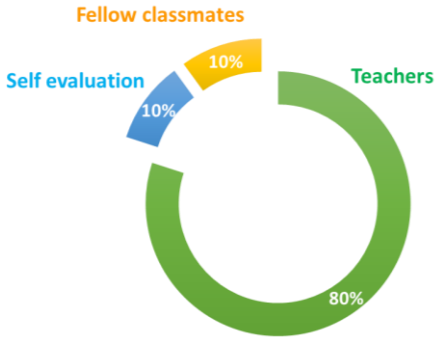

Fig. 2: *Evaluation of the project.*

In this way, each student has the possibility of evaluating themselves, their classmates, their teachers, and the group work process [5].
In order to correctly evaluate a work, students must be able to assess specific aspects of the work, and for this reason, the teachers prepared a rubric for the work and the presentation. Thus, students are also aware of their own faults and can carry out a more realistic self-evaluation and are even capable of taking concrete measures to advance in deep knowledge. Evaluation of the quality of the work corresponds to 75% of the total qualification, which must contain the descriptive plans, the main installations of the building and the corresponding 3D elements. The rubric is shown in Table 1.

The evaluation of the presentation of the work corresponds to 25% of the total qualification, and it should be considered that the presentation is clear and concise as well as that the members adjust their interventions to the time available. The rubric is shown in table 2.

Table 1*: Rubric to evaluated work quality [13]*

Marks	
0-2	Misconceptions
2-4	Errors in execution
4-6	Very important details are missing
6-8	Unimportant details are missing
8-10	Complete and elaborate designs

Table 2*: Rubric to evaluated presentation*

Marks	
0-2	Key parts not shown
2-4	Errors in the coordination between
4-6	Very important details are missing
6-8	Unimportant details are missing or does not fit the time
8-10	Complete and elaborate presentation in time

2.4 Perception of the students

In order to analyze the perception of the students about this work, a questionnaire has been prepared, which will be answered by the students once the project has been carried out and defended, but always before the final evaluation to avoid possible inferences and subjectivity in the answers provided. The possibility of adding a free comment to suggest possible changes or improvements for future courses has been added. Questionnaires have been employed as a crucial tool to measure students' perceptions of the methodology used and their own acquisition of competencies, aiming to assess educational efforts as well. The questionnaires are meticulously crafted to extract insightful feedback from students, providing valuable information about their experiences, understandings, and perspectives. For this reason, questions have been developed regarding project-based learning to acquire the specific competencies of this subject. Subsequently, after the self-assessment and peer evaluation process, students will be given access to the questionnaires. This enables educators to obtain a comprehensive snapshot of students' perceptions while minimizing possible biases. Additionally, by strategically scheduling the administration of these surveys before final evaluations, educators seek to foster an environment conducive to obtaining candid and constructive feedback, avoiding any undue influence that may arise post-assessment. Furthermore, the inclusion of an open section allows students to express nuanced opinions, suggest improvements, and offer recommendations for future iterations of the course, thus facilitating continuous improvement and refinement of educational practices.

3. RESULTS AND DISCUSSION

3.1. Progress of the activity

The purpose of this work is to show the results of the implementation of this methodology in a training activity, specifically in a group work in which the knowledge that is taught in a "theoretical" way in the master sessions must be applied in something industrial, being students need to collect information. To motivate the students, examples were shown, and two intermediate sessions were planned in which a control would be carried out, giving the student specific feedback about their strengths and areas of opportunity, in such a way that they can take advantage of possibilities and rectify the path [6]. This feedback plays a fundamental role, identifying all areas for improvement, but they are also advised on whether the level of work is adequate, trying to ensure that students do not spend excessive time on this work.

The transfers of the works and the presentations were carried out normally. Fig. 3 shows some of

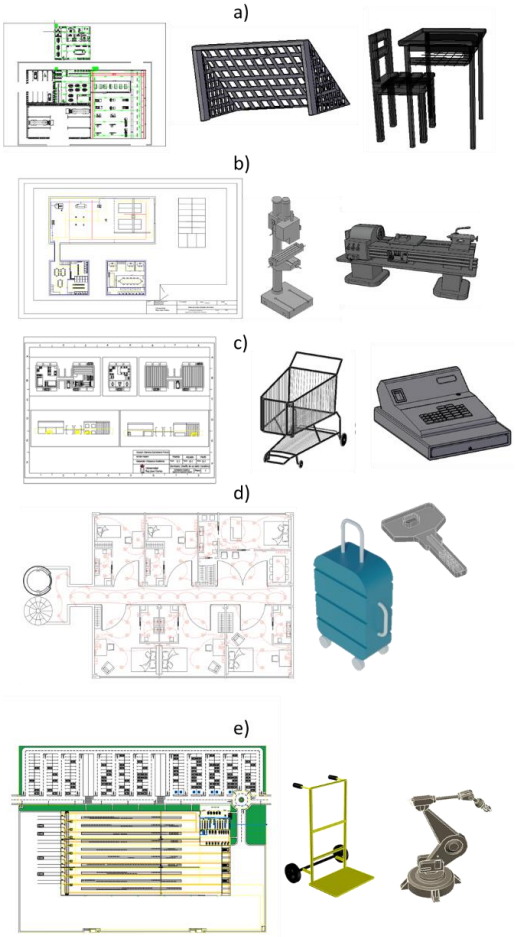

Fig. 3. *Designs made and evaluated by students in a) school, b) mechanical workshop, c) shopping mall, d) hotel and e) logistics center.*

the designs made by students for a design of a school, a mechanical workshop, a shopping mall, a hotel and a logistics center.

3.2. Evaluation of the activity

The students showed good behavior, being participatory with the rest of the classmates. As explained, the students had to give a grade to each group and to themselves. The results of the 11 groups are shown in the Fig. 4.

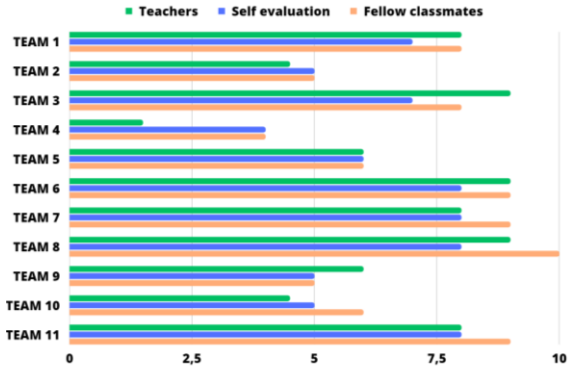

Fig. 4: *Qualifications of the work carried out by the 11 teams, both by the teachers and by the students themselves*

With these evaluations and considering the rules explained above, the final qualification of the activity was carried out. The average rating of the groups was 6.9 with a standard deviation of 2.3. It is detachable that if only teacher ratings were considered, the mean grade would be 7.1 with a standard deviation of 1.9. Therefore, it can be observed that the students were stricter in their assessments than the teachers. In order to analyze these variations, the differences between the rating given by the teachers and the one given by the students to their work have been represented in Fig. 5. A positive value in almost all the groups is showing, that is, the teachers have valued the work more highly grade than that of the students [14, 15]. There are three groups in which this trend is reversed and corresponds to the groups with the lowest scores. If now it is compared with the grades that have been given to the classmates [16], the result is different:

- There are groups in which the qualifications coincide with those of the teachers.

- There are groups that have been marked very harshly by their classmates, not valuing certain parts of the work, since the students have only seen the presentation.

- There are groups highly valued by colleagues, but in reality, they had execution errors that were not visible in the presentation.

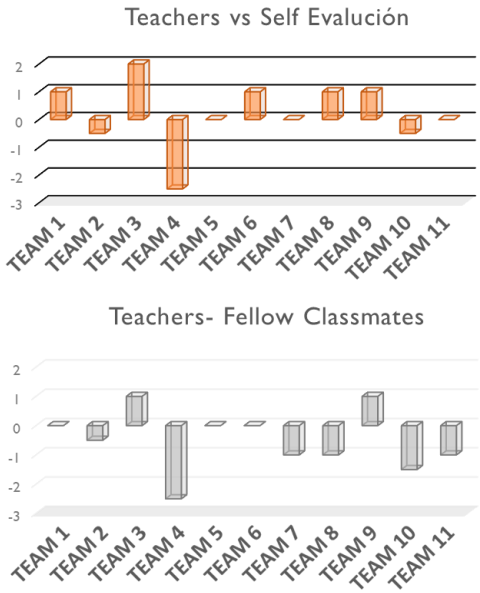

Fig. 5: *Difference between a) Teacher's qualification - student's own qualification, and b) Teacher's qualification – fellow classmate's qualification*

3.3. Perception of the student

In order to analyze the perception of the students about the realization of this project, a survey has

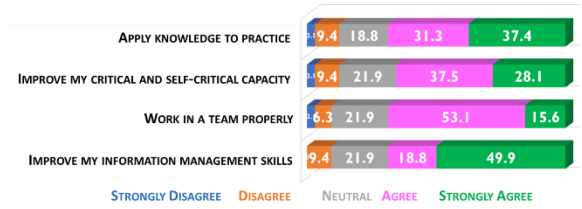

Fig. 6: *Student satisfaction about PBL in improvement of methodologic skills.*

been prepared that is answered by the students once the students have finished the work, but always before the final evaluation to avoid possible inferences and subjectivity in the answers provided [17].
The main results of these surveys on the perception of students can be divided into three types of acquired skills. On the one hand, they were asked if carrying out the seminar has helped them improve or acquire transversal skills such as teamwork or information management [18, 19]. Their results are shown in Fig. 6.

The perception was very satisfactory, allowing them to acquire these skills. 70% of students consider that this seminar has improved these skills, being the information management skill the best valued. On the other hand, the students have shown that working as a team in carrying out this work has been difficult for them, and that their classmates have not always allowed them to do it correctly.
Subsequently, they were asked about handling AutoCAD, differentiating 4 key concepts (normalization, working in layers, blocks, 2D and 3D). The results are shown in Fig. 7, more than 70% of the students believe that this activity is adequate to acquire that better skill in the use of the software.

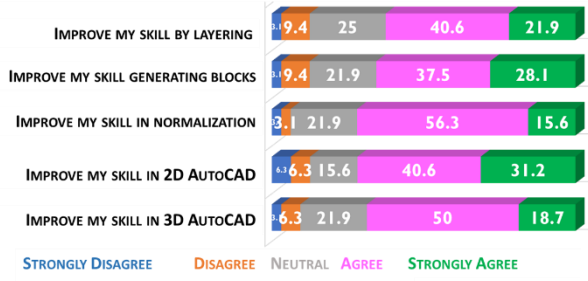

Fig. 7: *Student satisfaction about PBL in improvement of skills related to CAD software.*

And finally, a high percentage of students consider that with this activity they have been able to achieve two of the competencies of the subject (Fig. 8). Finally, to conclude, the competencies that must be acquired in this matter have been sought, such as developing spatial vision capacity and knowledge of graphic representation techniques as well as knowing and applying engineering tools, techniques or equipment, including software.
More than 70% of the students strongly agree that this activity improves visual skills. A slightly smaller percentage considers that this seminar helps them learn industrial tools.

In response to the results of the questionnaire, the realization of this group seminar has been well valued by the students, allowing them to acquire skills in the use of AutoCAD, both 2D and 3D, helping them to improve in the generation of blocks and layers, fundamental transversal tools in the practical sessions. It is very remarkable that the students consider that this work helped

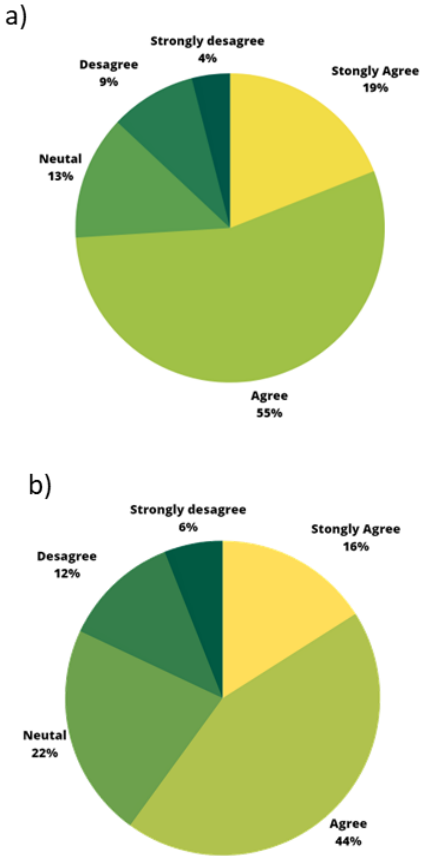

Fig. 8: *Student satisfaction about PBL in a) Develop my capacity for spatial vision and knowledge of graphic representation techniques, b) Know and apply engineering tools, techniques or equipment, including software programs.*

them to work in a team properly, and to improve their critical and self-critical capacity.

3.4. Differences between traditional learning (TL) and the project learning (PLB)

Once the work has been completed, the main differences that can be extracted are:

- While in TL, students are passive receivers, with this active methodology PBL, students actively participate in the project.
- In PLB, students take responsibility for their work, and the teacher becomes a guide.
- In active methodologies, as PLB, students investigate a topic to learn, unlike TL.
- Teachers are no longer the only evaluators, in PBL, students participate in this task, being able to assess it since they have done a job with which to compare [20].
- Unlike the traditional methodology, in PLB, different solutions are now possible, all of them valid, and leading to different conclusions.
- The students are usually motivated with the PLB, and the oral presentation teaches students to speak in public and defend their ideas.

4. CONCLUSIONS

Active methodologies play a vital role in addressing the challenges associated with teaching practical subjects, particularly in the initial stages of a degree program, where students often struggle to grasp the relevance and applicability of foundational concepts. Graphic Expression, with its multifaceted components such as spatial vision, software proficiency, technical drawing, and interpretation of plans and diagrams, exemplifies the complexity of such subjects. Project-based learning emerges as a powerful solution to these challenges, offering a dynamic framework that fosters deeper engagement and understanding among students. Central to the success of this methodology is effective group management, which necessitates careful guidance and support from educators. The incorporation of project-based learning in Graphic Expression has revealed promising outcomes, particularly in terms of student evaluation and perception. The process of self-assessment and peer evaluation has provided valuable insights into students' rigorous self-appraisal, highlighting their propensity to critically evaluate their own work and that of their peers. This heightened sense of accountability has not only contributed to a more thorough mastery of subject-specific skills but has also bolstered students' capacity to deliver and receive constructive feedback effectively. Moreover, the overwhelmingly positive perception of students towards this methodology underscores its efficacy in nurturing both transversal competencies, such as information management and teamwork, and specialized skills relevant to the subject area. By providing a platform for hands-on exploration and collaborative problem-solving, project-based learning has not only deepened students' understanding of graphic expression but has also sharpened their proficiency in spatial visualization, CAD tool management, and interpretation of technical drawings and diagrams. In essence, the adoption of project-based learning in Graphic Expression has proven to be a transformative pedagogical approach. It has empowered students to transcend traditional learning boundaries, fostering a holistic development that extends beyond mere acquisition of knowledge to encompass critical thinking, collaborative skills,

and self-efficacy in real-world applications. Through this integrated approach to teaching and evaluation, educators have successfully enhanced students' perception of their own capabilities, laying a solid foundation for their future academic and professional endeavors in the field of engineering.

5. REFERENCES

[1] San Martín Gutiérrez, S., Jiménez Torres, N., Jerónimo Sánchez-Beato, E., La evaluación del alumnado universitario en el Espacio Europeo de Educación Superior, (2016) Aula Abierta, Volume 44, Issue 1, Pages 7-14.

[2] Glassey, J., Novakovic, K., & Parr, M. (2013). Enquiry based learning in chemical engineering curriculum supported by computer aided delivery. Education for Chemical Engineers, 8(3), e87–e93. https://doi.org/10.1016/j.ece.2013.06.003

[3] Mills, J. (2003). Engineering education, is problem-based or project-based learning the answer. https://www.semanticscholar.org/paper/5b40d76d09838f53c777e6ba2192ba1b11023dd9

[4] Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. Educational Psychologist, 26(3–4), 369–398. https://doi.org/10.1080/00461520.1991.9653139

[5] Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. The Elementary School Journal, 94(5), 483–497. https://doi.org/10.1086/461779

[6] Rodríguez, C. and Fernández-Batanero, J., 2017. Evaluación del Aprendizaje Basado en Problemas en Estudiantes Universitarios de Construcciones Agrarias. Formación universitaria, 10(1), pp.61-70.

[7] Garrido de la Torre, M. E., Pérez - Zuriaga, A. M., Martínez - Ibáñez, V., López Maldonado, G., & Cuadrado Tarodo, Á. (2020). PIME Aprendizaje Basado en Proyectos: Ingeniería de Carreteras e Ingeniería Geotécnica. Libro de Actas IN-RED 2020: VI Congreso de Innovación Educativa y Docencia en Red.

[8] ¿Qué es el Aprendizaje Basado en Proyectos o ABP? (2020, July 21). Thinkö. https://thinkoeducation.com/blog/que-es-el-aprendizaje-basado-en-proyectos-o-abp/

[9] Morán-Barrios, J., Ruiz de Gauna, P., Ruiz Lázaro, P.M., Calvo, R., (2020) Metodologías complementarias de aprendizaje para la adquisición de competencias en la formación de especialistas y actividades profesionales confiables. Educación Médica, Volume 21, Issue 5, Pages 328-337.

[10] Hernáiz-Pérez, M., Álvarez-Hornos, J., Badia, J. D., Giménez, J. B., Robles, Á., Ruano, V., & San-Valero, P. (2021). Contextualized project-based learning for training chemical engineers in graphic expression. Education for Chemical Engineers, 34, 57–67. https://doi.org/10.1016/j.ece.2020.11.003

[11] De Vivo, Kristin. "A New Research Base for Rigorous Project-based Learning." Phi Delta Kappan 103.5 (2022): 1. Web.

[12] Madrimasd.org. Retrieved March 20, 2023, from https://www.madrimasd.org/sites/default/files/G

U%C3%8DA%20VERIFICACI%C3%93N_%20v3.pdf.

[13] Alique, D., Linares, M. (2019) The importance of rapid and meaningful feedback on computer-aided graphic expression learning, Education for Chemical Engineers, 27, pp. 54–60.

[14] Yu, F.-Y., & Chen, C.-Y. (2021). Student-versus teacher-generated explanations for answers to online multiple-choice questions: What are the differences? Computers & Education, 173(104273), 104273. https://doi.org/10.1016/j.compedu.2021.104273

[15] Gao, X., Wang, L., Deng, J., Wan, C., & Mu, D. (2022). The effect of the problem based learning teaching model combined with mind mapping on nursing teaching: A meta-analysis. Nurse Education Today, 111(105306), 105306. https://doi.org/10.1016/j.nedt.2022.105306

[16] Laelasari. (2018). Self regulated learning trough project base learning on the prospective math teacher. Journal of Physics. Conference Series, 983(1), 012156. https://doi.org/10.1088/1742-6596/983/1/012156

[17] Cutumisu, M., & Schwartz, D. L. (2021). Feedback choices and their relations to learning are age-invariant starting in middle school: A secondary data analysis. Computers & Education, 171(104215), 104215. https://doi.org/10.1016/j.compedu.2021.104215

[18] Gargalo, C. L., Caño, S., Caccavale, F., Gernaey, K. V., & Krühne, U. (2022). Educational computer-aided tools towards industry 4.0: Recommendations and BioVL. In Y. Yamashita & M. Kano (Eds.), Computer Aided Chemical Engineering (Vol. 49, pp. 1273–1278). Elsevier.

[19] Gallego Durán, Francisco J, Carlos-José Villagrá Arnedo, Rafael Molina Carmona, and Faraón Llorens Largo. "COVID-proof: Cómo El Aprendizaje Basado En Proyectos Ha Soportado El Confinamiento." Campus Virtuales 10.1 (2021): 73-88. Web.

[20] Feeney, S., Machicado, G., Larrosa, L., El Aprendizaje Basado en Proyectos como política de enseñanza: algunos interrogantes. Praxis educativa, Vol. 26, No 3 septiembre – diciembre 2022. E - ISSN 2313-934X. pp. 1-23. https://dx.doi.org/10.19137/praxiseducativa-2022-260308