CAPÍTULO 24. **DIDACTIC METHODOLOGIES IN TECHNICAL EDUCATION**

Cesar Antonio Rodríguez González

Universidad de Huelva

José Antonio Hernández Torres

Universidad de Huelva

Ángel Mariano Rodríguez Pérez

Universidad de Huelva

Julio José Caparros Mancera

Universidad de Huelva

1. INTRODUCTION

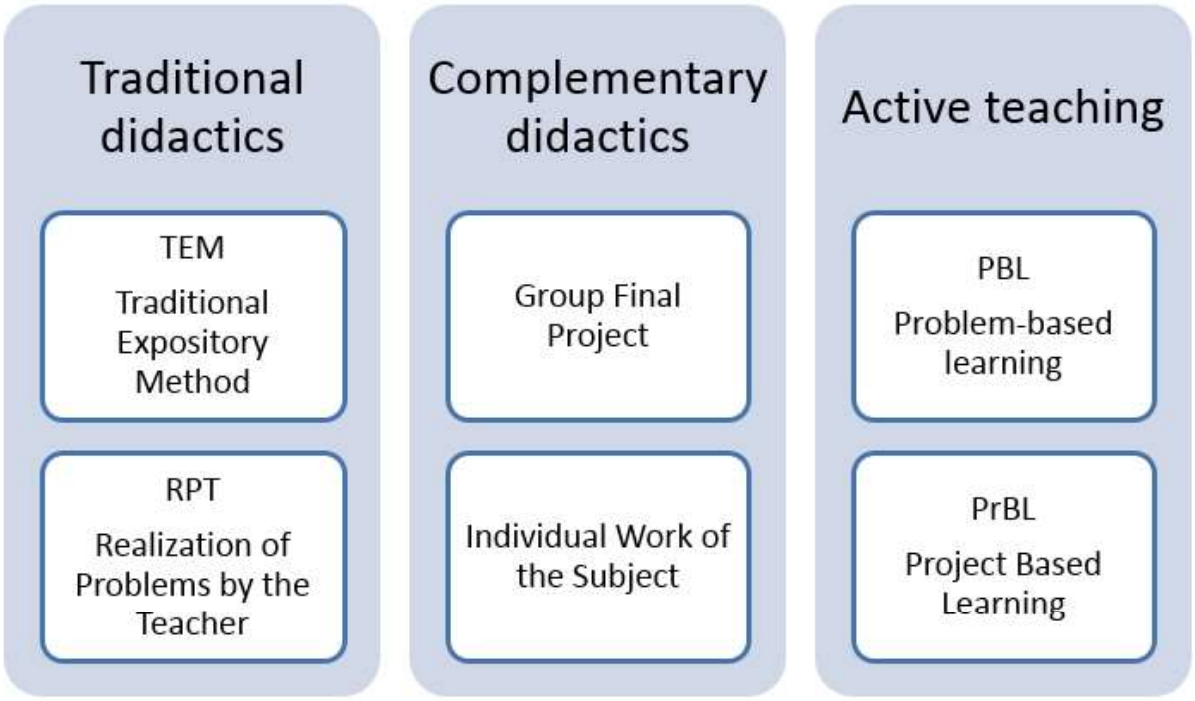
This work develops a review based in the usual didactic methods in technical teachings and the obtaining some clarifications on their application. The teaching of engineering and architecture, with its own characteristics, uses didactics with the proper orientations that its practical nature prints (Alves, y otros, 2019). What unites one didactic with another, before any subsidiary objective, is the need for a teaching-learning process (García-Llamas, 2003). Without knowledge to transmit, and some agents to participate, we cannot speak of didactics. Within these didactics, active didactics such as Problem-Based Learning (hereinafter ABP) and Project-Based Learning (hereinafter ABPr) stand out (Prince, 2004). Both active didactics are very similar, but they also have some distinctive elements that we will try to elucidate. The object is none other than to avoid confusion between didactics that, due to the name or other aspect, are often confused with what a PBL or PBL is, implies and needs (Prince, 2004). A diagram with the commented didactics in Figure 1.

2. EXPOSITORY METHOD

The expository method (hereinafter MET), consists of giving a master class, unambiguous for the most part in the transfer of information from the teacher to the student, with the exception of question sessions (Costa, Moro, Miranda, & Arnold, 2020). In recent times, it is usually accompanied with the support of an overhead projector. It is the most common traditional method, not only in

engineering and architecture, but also in the rest of the fields of knowledge of university studies. This was not always the case, since there are indications that, in some old special schools of engineering or architecture, workshop and fieldwork had a considerable weight in the training and evaluation of students. But with the integration in Spain of the technical schools in the Ministry of Education, and academic freedom linked to teachers with more or less traditional didactic approaches of the Faculties, this method has become the default generic method for technical schools. And this, even, in eminently practical subjects, which has led to an increased difficulty in passing certain subjects, with respect to others that receive active teaching methodologies. We all know that, in most cases, engineering or architecture subjects are evaluated mainly through objective tests based on -or including as a fundamental part- problems. However, in class throughout the teaching period, sometimes there are not too many problems to exemplify the application of the knowledge taught. The autonomous work of the student in these cases -as in many others- becomes fundamental.

Figure 1: Usual didactics in technical teachings.



Source. Own elaboration

3. REALIZATION OF PROBLEMS BY THE TEACHER

The realization of problems by the teacher (hereinafter RPD) consists of a MET-type exposition, but accompanied by a frequent realization of problems, in

such a way that at the end of the course of the subject the student has a collection of problems carried out in class by the teacher (Rodriguez & Bonner, 2018). This didactic is preferable, in the general case, to the MET exclusively for technical teaching. Traditionally, the usual didactics in engineering or architecture subjects that require problem solving has consisted of a presentation accompanied by a series of type exercises solved by the teacher. This teaching method is an evolution with respect to the MET exclusively. In reality, both teaching methods are usually accompanied in those subjects that contain theory and problems; such as the subjects of Theory of Structures (and its denomination variants). The fundamental issue, and often at the request and/or for the benefit of the students, is to be able to have a wide collection of problems, so that the cases seen in class become standard cases. In subjects such as General Physics in the first year of engineering and architecture of all branches, there is a good bibliography on the matter. The same happens with Vector Mechanics, a fundamental discipline in some branches at the Degree level (Civil Engineering, Mechanical Engineering, Architecture and others). But in certain subjects a major problem arises: there is very little literature on problems. In these cases, the publication of specific notes that include type problems for the subject is mandatory in order to give the student adequate support, if this didactic method is to be followed. But this is not always the case, and from our information we know that in the end it is the students who have to compile, in a somewhat informal way, problems and exercises from other years.

This didactic method is usually accompanied by the MET, as has been mentioned. There are many subjects in higher or Master's courses that adapt well to this method almost exclusively: for example, some very specialized subjects that are usually found in the form of extensions of previously taught subjects: Extension of Geotechnics, Hydraulic Machines II, Theory of Circuits II, Advanced Calculation of Structures, Fixation Elements and Support of Industrial Machines and Equipment, and others. In these cases, the MET has already been de facto taught in the corresponding previous subject, so that the teacher performs problems immediately, or shortly after the subject is taught.

4. GROUP WORK AND SUBJECT WORK

In this section we include two methods that are usually related in teaching learning in engineering and architecture: work in groups (more or less fixed), and the final project of the subject (Clegg, Billau, & JAG, 1978). These are not usually methods, exclusively, for a given subject, but rather methods combined with the MET and the RPD. For this reason, these methodologies are grouped in the attached diagram as complementary didactics.

When the subjects (pre-Bologna) were annual, the student was usually evaluated in such a way that, in some subjects, a final project completed throughout the academic year was required, which accompanied the exam; either as a requirement or as support for the final grade (Climent & Martínez, 2018). But nowadays, with study plans in which the subjects hardly have a

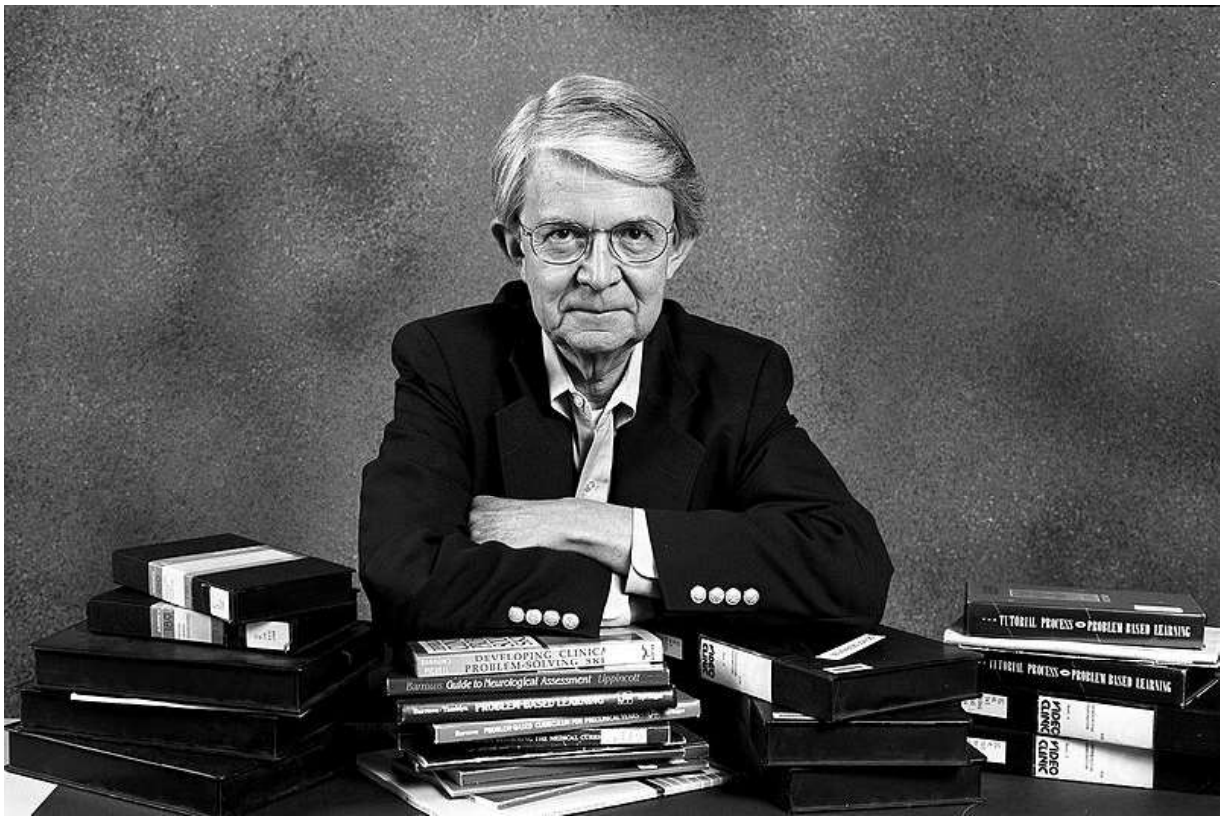
semester in many cases, there is a tendency to include a final project as part of the student's autonomous work in subjects of almost all courses and levels. The option of evaluation without work, or with an additional independent exam on work subjects, is usually included in the corresponding teaching programs. As the subjects multiply, it is logical that the work in many of the subjects will continue. The student more as a hindrance than as an advantage, usually assumes the dedication to the work of the subjects, if these are disconnected with the knowledge that is evaluated in the final exams.

Regarding group work, the formation of small groups (2, 3 or 4 students) fixed throughout the course, and all of them signing the final work of the subject, has also been frequent. For example, it was very common (and still is in some schools) that the subject of Projects (with its variant names: Projects and Entrepreneurship, Technical Office, etc.) required the delivery of a small project at the end of the course. This project was subject to evaluation, review, tutoring, and not infrequently, defense. This way of proceeding, as the subjects are included in the plans predominantly in a single semester, establishes a hectic pace for the student at the end of the semester in question. On the other hand, the professor in the current plans, sometimes has to teach not a few subjects, dividing the dedication to each of these and making it difficult to carry out, review and audit the final works of the subject.

5. PROBLEM-BASED LEARNING

PBL is a specific didactic in which the teaching and learning process is characterized by the confrontation of students with more or less complex problems, real most of the time, and for which they will be able to have whatever material they consider necessary PBL -like its sister didactics PBLr- is an active didactic (Barrows & Tamblyn, 1980). Active learning methodologies grant a fundamental role to the student in the training process, since the development of the teaching-learning process depends largely on the attitude of involvement and responsibility that he develops towards it (Pereira, Barreto, & Pazeti, 2017). The results of the application of these active methodologies are very positive, as they provide the student with greater involvement, motivation and interest, greater internalization of the knowledge acquired, greater development of professional and transversal skills, greater integration and relationship of the new knowledge with others. A lower dropout rate (ERAGIN , 2012; Kroll & D. Artzi, 2011) . It is with this statement that we begin the section, since in our opinion it synthesizes the two essential aspects of active teaching methodologies: the active role of the student in the teaching-learning process and a better integration of the knowledge acquired.

Figure 2: Howard S. Barrows (1928 –2011). Precursor of Problem Based Learning. Southern Illinois University School of Medicine.



Source. Portrait of Howard S. Barrows by James R. Hawker (2011). CC BY-SA 3.0 (Free to share and adapt).

The active role of the student in active didactics is a drastic change with respect to the MET. In this latest didactic methodology, the student attends as a passive spectator. Therefore, the assimilation of knowledge does not occur ipso facto, or not predominantly in its entirety, since it requires further study, either alone or accompanied, but in no case in the classroom at the time of the master class. Active methodologies, in their different variants, do not guarantee complete assimilation at the precise moment of the class, nor do they exempt the dedication to independent study of class hours. Nevertheless, there is a process of knowledge assimilation, which goes from mere knowledge through a path that lead to acquiring an expertise, which started in the same classroom. The best integration of knowledge has different facets, such as requiring a link with other branches of knowledge due to certain problems or the project that is proposed, a better development of skills according to the students' own perception (Du & Kolmos, 2006). Above all an approach to future professional practice for technical education (Fernández & Duarte, 2013).

With regard to the latter, we can add that in the didactics of technical education, active methodologies are, if possible, as important as or more so than

in other types of studies, given the future responsibility of the student in the exercise of what will be their profession. Since the decision-making associated with future professional practice as an engineer or architect will entail an added responsibility, having tried or experienced it previously implies an approach to know-how that expository didactics alone will hardly be able to provide. In turn, and in the present university student, a reduction in the dropout rate by technical education students, and having an efficient method for the development of professional skills, make active methodologies an alternative option compared to other methodologies of only expository cut. However, given the variability of subjects to be taught, training differences by specialties, teacher training and experience, different active teaching methodologies and other factors, each case will require the corresponding study from which to deduce the corresponding implications. Next, in a synthetic way, the essential elements of PBL are exposed:

1) Student-centered learning.

2) Generation of learning in small groups (no more than 4 students).

3) The teacher acquires the role of facilitator.

4) The core of generating organizational and learning capacities lies in the generation of problems.

5) Facing problems builds skills.

6) Self-directed learning generates new knowledge.

6. PROJECT-BASED LEARNING

In this section, the relationship of PBL with another close and very interesting teaching method, usually applied in architecture schools, and more recently in the development of product manufacturing are commented.

Project-based learning (PBL). Regarding the relationship between PBL and PBL, referring in our case to engineering and architecture, both are active methodologies. However, there are some differences. Some authors consider that project-based learning is an active methodology where the focus is on a final product, design or project to be developed; in short, an idea that is intended to become a reality (Mettas & Constantinou, 2008). PBL is based on a project, which, is developed throughout the teaching of the subject in question, this being the essence of its pedagogical strategy (Rodríguez-Sandoval & Cortés-Rodriguez, 2010). It can be said, therefore, that PBL always has (and it is a conditioning factor) a central axis: the project itself. The PBL, from the point of view of the authors, is especially suitable for the teaching-learning of subjects in which design plays a fundamental role, such as, for example, in subjects of Technical Education Projects. In the case of Constructions, the ABP is, from the point of view of the authors, more versatile than the ABPr since the former is not limited to a single project but to problems associated with practical cases, including problems of machinery, installations, and execution of works.

In any case, although ABP refers in its name to problems and ABPr to projects, in the field of architecture and engineering they are not mutually exclusive methodologies, so the assessments about their similarities and differences must be understood with flexibility (Rodríguez & Fernández-Batanero, 2017). We will not insist too much on separating both didactics, but rather on their unifying character: both are active methodologies with a very similar start-up in class in both cases (formation of work groups, material for autonomous study, establishment of milestones, etc). However, if you want to specify its nuances in order to better see its suitability for a given subject or matter, here are some slight differences that may be useful:

- While in the PBL sessions the composition of the work groups can be varied throughout the course when the problem or case to be solved changes, in the course work with a PBL the component members of the groups do not vary throughout the development of the teaching program.

- In both, ABP and ABPr, group work is a fundamental means for the development of didactics. These didactics require (usually) other didactics such as MET and RPD during a certain period, or in specific sessions. While in PBL the course usually includes several cases or problems to solve; In the PBL, the project -unique throughout the course- is the fundamental means to proceed with the capture of concepts by the students. The proper selection of cases in PBL and of the project in PBL is essential. A simple or uninteresting case in PBL can be corrected or amended with a later, more advanced case, thus grading the difficulty. The selection of a suitable project in PBL is critical, as there is no turning back once the course has advanced.

7. CONCLUSIONS

In technical teaching, it is possible to state:

- The adequacy of one didactic or another to the teaching of a certain subject will depend on the contents to be taught. Not all subjects in engineering or architecture are refractory to the MET due to their content. Some subjects have adapted reasonably well to this didactic method, for example, the subjects on legislation. Even so, MET, as the only and exclusive didactic method, is not advisable in all types of subjects typical of technical education.

- Regarding RPD, a very common didactic in technical teaching, with respect to PBL and PBL, the teacher still plays an active role in didactics, so we cannot consider this teaching methodology as an active didactic or a variant of PBL . But we consider that it is preferable to the MET exclusively in technical teachings.

- For certain subjects, PBL and PBL are configured as an effective teaching method, and in turn, more efficient than the method that combines MET and RPD

- The MET and RPD continue to be essential to lay the foundations for the subjects taught, regardless of whether it is combined with other active teaching methods. We do not recommend an ABP or an ABPr without any training given

in the didactic form of the MET and/or RPD. However, the reduction to an essential minimum can be achieved with the appropriate teaching material and the help of the virtual platform.

REFERENCES

Alves, A., Moreira, F., Carvalho, M., Oliveira, S., Malheiro, M., Brito, I., . . . Teixeira, S. (2019). Integrating Science, Technology, Engineering and Mathematics contents through PBL in an Industrial Engineering and Management first year program. *Production. 29. 10.1590/0103-6513.20180111.*

Barrows, H., & Tamblyn, R. (1980). *Problem-based learning: an approach to medical education*. New York: Springer Publishing Company.

Clegg, A., Billau, D., & JAG, K. (1978). "Practical training in foundry technology for potential professional engineers at Loughborough University of Technology". *Eur. J. Eng. Educ., 3*(1), 161-171.

Climent, J., & Martínez, J. (2018). Algunas estrategias docentes en las asignaturas de matemáticas de los primeros cursos universitarios. *Revista del Congrés Internacional de Docència Universitària i Innovació (CIDUI), 4.*

Costa, J., Moro, S., Miranda, G., & Arnold, T. (2020). Empowered learning through microworlds and teaching methods: a text mining and meta-analysis-based systematic review. . *Research in Learning Technology, 28.*

Du, X., & Kolmos, A. (2006). Process competencies in a problem and project based learning environment. *35th SEFI annual conference: Engineering education and active students.*

ERAGIN . (2012). *Programa de formación del profesorado en metodologías activas de enseñanza.* (Universidad del País Vasco) Recuperado el 26 de 02 de 2022.

http://www.ehu.eus/es/web/sae-helaz/eragin

Fernández, F., & Duarte, J. (2013). El aprendizaje basado en problemas como estrategia para el desarrollo de competencias específicas en estudiantes de ingeniería. . *Formación Universitaria, 6*(5), 29-38.

García-Llamas, J. (2003). *Métodos de Investigación en Educación. Investigación cualitativa y evaluativa.* . Madrid: UNED.

Kroll, E., & D. Artzi. (2011). "Enhancing aerospace engineering students' learning with 3D printing wind-tunnel models" . *Rapid Prototyp Journal.* .

Mettas, A., & Constantinou, C. (2008). The technology fair: a project-based learning approach for enhancing problem solving skills and interest in design and technology education. *International journal of technology and design education, 18*(1), 79-1.

Pereira, M. A., Barreto, M. A., & Pazeti, M. (2017). Application of Project-Based Learning in the first year of an Industrial Engineering Program: lessons learned and challenges. *Production 27.*

Prince, M. (2004). Does active learning work? A review of the research. *Journal of engineering education, 93*(3), 223-231.

Rodriguez, C., & Bonner, E. (2018). The impact of teacher questioning and open ended problems on mathematical communication. . *Journal of Teacher Action Research, 4*(3), 68-89.

Rodríguez, C., & Fernández-Batanero, J. (2017). Evaluación del aprendizaje basado en problemas en estudiantes universitarios de construcciones agrarias. . *Formación universitaria, 10*(1), 61-70.

Rodríguez-Sandoval, E., & Cortés-Rodriguez, M. (2010). Evaluación de la estrategia pedagógica "aprendizaje basado en proyectos": percepción de los estudiantes, http://www.scielo.br/pdf/aval/v15n1/v15n1a08,. *Revista da Avaliação da Educação Superior, 1*(15).