



Cooperative learning at the Analytical Chemistry laboratory

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Resumen.

El aprendizaje cooperativo es un sistema de organización del trabajo y de motivación, en el que el alumno es responsable de su aprendizaje y el de sus compañeros. A diferencia de los sistemas individualista y competitivo, las metas son grupales. La aplicación sistemática de este sistema da respuesta a tres principios básicos del Espacio Europeo de Educación Superior (EEES): participación y autonomía del estudiante, utilización de metodologías activas y papel del profesorado como agente facilitador del aprendizaje. Brevemente, con esta metodología se divide la clase en pequeños equipos, que reciben unas consignas de actuación a partir de las cuales planifican el trabajo del grupo. Cada miembro del grupo será responsable de áreas específicas que será necesario realizar satisfactoriamente para el éxito del grupo. En esta comunicación se plantea la aplicación del aprendizaje cooperativo para el aprovechamiento efectivo de las clases prácticas de laboratorio de análisis químico, dirigido a alumnos de último curso de la titulación de Ingeniería Química. La práctica en concreto consiste en la verificación de un equipo de HPLC-UV/Vis, para comprobar la conformidad con las especificaciones del fabricante. Además, esta metodología permite trabajar

competencias transversales como razonamiento crítico, trabajo en equipo, gestión de proyectos y comunicación entre otras.

Palabras Claves: Aprendizaje cooperativo, trabajo en equipo, metodologías activas de aprendizaje, Aprendizaje centrado en el alumno.

Abstract.

Cooperative learning is a work organizational system to motivate students, who become responsible for their own and their team mates learning. Unlike the individualistic and competitive learning styles, in cooperative learning student achievements occurs only when the other students in the group also achieve the objectives and rewards. Systematic application of this methodology helps reaching three basic principles of the European Higher Education Area (EHEA): student participation and autonomy, active methodologies application and lecturer role as facilitator in the learning process. In short, this methodology involves splitting up the class into small teams, which have to organize their self-workload to complete assignments and reach objectives previously established. Each team member is responsible for specific tasks that must be properly completed for the final success of the group. In this communication we propose the cooperative learning for effective laboratory lessons of analytical chemistry, aimed to last year students of chemical engineering. The specific assignment involves the verification of a whole equipment of liquid chromatography (HPLC) with spectrophotometric detection (UV-Vis) to check compliance with supplier specifications. In addition to specific competences, applying cooperative learning approach, students develop generic competences such as critical thinking, working with other, project management and communication among others.

Keywords: Cooperative learning, team working, active learning methodology, student-centred learning.

1. Introduction.

The European Higher Education Area (EHEA) is based on three basic principles: i) boosting the participation and autonomy of students, ii) use of more active methodologies and iii) role of teachers as facilitator to create learning environments that encourage students.

The use of lectures as the only teaching method at the University leads to a passive attitude by students, since it reduces their active participation in the subject and motivation. Therefore, as a measure to improve the teaching-learning process, it is needed to introduce new teaching methodologies, or at least combine them with traditional methodologies, in order to motivate students boost their participation.



1.1. Cooperative learning.

Cooperative learning is the instructional use of small groups so that students work together to achieve shared learning goals and complete jointly specific tasks and assignments, thus maximizing their own and each other's learning. In cooperative learning, unlike competitive or individualistic, students are responsible for their own learning and that of their group members. Group members share the responsibility of accomplishing learning goals, that is demonstrating competence or mastery in the subject area being studied (De Miguel Díaz et al, 2005; Johnson and Johnson, 1985). According to Johnson and Johnson (1985), in cooperative learning system each student reaches own goals if each group member reaches theirs. Students success is because both, their personal effort and the work done by the rest of group members. All group members have something to contribute, and the interaction between them is essential for the benefits that each of them obtain in the learning process.

Not all groups are cooperative (Johnson and Johnson, 2009). Placing people in the same room, seating them together, telling them they are a group, does not mean they will cooperate effectively. Five essential elements are need for an effective cooperative learning (Johnson y Johnson, 1994, 1999; Valero, 2013):

- Positive interdependence (a sense of sink or swim together): Teachers must give clear tasks and group goals, and every group member perceives that they are linked with each other in a way that one cannot succeed unless everyone succeeds (If one fails, the whole group fails). If there is no positive interdependence, there is no cooperation. Some strategies to achieve effective positive interdependence are:
 - Proper working load, so that the distribution of tasks among group members is absolutely necessary.
 - Joint incentives.
 - Distribution of different resources to each group member. These resources would be useful only if they are shared with the group.
 - Complementary roles assignment (responsibility, secretary, moderator, etc ...) to each group member.
- Individual and group accountability (each of us has to contribute and learn): The group must be accountable for achieving its goals. Each student is accountable not only for their own learning but they must also commit themselves to the group common goals. Therefore, it is not possible for any group member to work only in their individual tasks, paying no attention to the work done by the rest of the group. Once the group is clear about its goals, some strategies to achieve an effective individual and group accountability are:

- Measurement of its progress in achieving these goals.
- Measurement of each group member individual effort.
- Face-to-face promotive interaction: Promotive interaction occurs when members share resources and help and support each other's efforts to learn. Interaction between group members should be straight and continuous. Therefore all of them should have compatible schedules. Furthermore, using some time to work at the classroom could be sometimes convenient (this would allow also the teacher to check and observe the group performance).
- Student learning of required interpersonal and group skills: in addition to the academic subject matter (task work), students are required to learn, develop and apply basic interpersonal and group skills, such as communication, trust, leadership, decision making, conflict resolution, etc. The group should be able to reach agreements, constructively challenge others and/or accept criticisms. Teacher must be prepared to help resolve difficulties and eventual conflicts. In this sense It is advisable to offer, at the beginning of the course, training in aspects such as i) decision making, ii) establishing group working rules, iii) offering constructive criticisms, iv) information analysis and problem solving, v) prioritizing, organizing and sharing tasks as well as setting deadlines, vi) managing meetings and drawing up minutes.
- Group processing: it is important a frequent and systematic assessment and monitoring of the group performance, to check how well group members are achieving their goals and maintaining effective working relationships. They should identify positive and negative issues as well as improvement opportunities. Some strategies for group processing include:
 - Questionnaires to facilitate the use of reflection, great for identifying the first difficulties.
 - Planning some time for thinking in order to highlight difficulties that may be emerging during the development of the whole activity.

2. Objectives.

In this communication we propose the application of cooperative learning for the effective use of laboratory practical classes of chemical analysis, aimed at students in their final year of the degree in Chemical Engineering. Specifically, the lab work involves the verification of all components of an analytical equipment to check their compliance with the manufacturer's specifications. In this case the equipment used is a high performance liquid chromatograph (HPLC) with detection by UV-Vis spectrophotometry. The variables to be verified are pumps flow rate, column oven temperature, linearity and accuracy of the injector, as well as the accuracy and linearity of the detector lamp wavelength.

2.2. Specific competences.

The main learning goals of the proposed laboratory sessions are to develop the required competences to run and verify and HPLC equipment. This main goal is split up in smaller learning goals, so that at the end of the laboratory sessions the students should be to:

- Briefly explain liquid chromatography fundamentals and classify its different modalities.
- Be aware of the importance of equipments management and preventive maintenance to obtain reliable analytical information.
- Evaluate different alternatives for the verification of each module of HPLC equipment and choose the more convenient. Justify the choice by specifying the considered criteria.
- Explain and be able to apply the procedures to calibrate and verify the different modules of an HPLC equipment.
- Plan and execute all activities needed for the verification the HPLC equipment.
- Be able to identify and correct the main causes of error in chromatographic determinations. Analyze critically the results obtained.
- Be competent to run an HPLC (both hardware and software).

2.3. Transversal key competences.

Cooperative group work enable students to develop different transversal attitudes, knowledge, and skills that foster (De Miguel Díaz and collaborators, 2005):

- Team working: planning and management of meeting, bringing creative and feasible ideas, group conflict resolution.
- Project management: developing a working plan and its monitoring and evaluation.
- Self-learning, critical thinking and creative problem solving:
 - Searching, selection, organization and evaluation of information.
 - Transfer and application of knowledge to real situations.
- Personal management: facing uncertainty, understanding verification and consensus, focusing the group work/follow instructions, time management.



- Communication: oral and writing communication, active listening.

3. Proposal.

3.1. Creation of working group and organization.

In the first working session students are split up into groups of 3 - 4 members as much heterogeneous as possible (gender, interests, abilities, motivation, performance, etc..). These are the so-called cooperative base groups, which are long-term, cooperative learning groups with stable membership and shared tasks/learning goals. It is advisable to avoid establishing larger groups in order to avoid free riding and encourage both positive interdependence and personal face to face interaction. Subsequently, the roles of each group member are established, which also helps to achieve positive interdependence. These roles, which could rotate and be exchanged in each session, and could be (Pujolàs, 2003, Valero, 2013) although not limited to:

- Group responsible: coordinates the group work coordination, encourages the group members to finish their tasks by the planned date, supervises regular team checkings and distributes tasks to the team workers.
- Secretary: take minutes, fulfils in forms and assumes responsibility for the final work that the group must deliver.
- Verifier: makes clear what the learning goals are, confirms the understanding of each group member.

During the progress of the practical classes there will be also meetings with members of different groups with similar assignments and tasks, who became expert on specific topics (meeting of experts).

Once the groups are established, the teacher provides information about the main objective of the practical laboratory classes, and explains the essentials and fundamentals of group and cooperative working. He also offers tips on group working and addresses issues related to interpersonal and group skills mentioned in section 1.1.

At this first meeting, the working material is also provided, which comprises specific literature on chromatography, electronic resources available on the internet and the user manual of the analytical equipment (Agilent Tech. HPLC, 1100 series). All this material will be provided in English, so that students are forced to at least analyze, understand and synthesize information on that foreign language. Then tasks to be carried out inside and outside of the laboratory/classroom are planned. These tasks are also split up into 3-4 blocks (according to the group size), and each group member is responsible for one of them. However, at the end of the practical laboratory class, all group members should be capable of explaining and/or presenting any of the work sections in a written test.

3.2. Previous tasks.

Self-work outside the classroom:

- To study of recommended bibliography and working material provided by the teacher.
- Detailed solution to questions and activities related to equipment management and maintenance.

Group work in the classroom (base group meeting):

- Comparison of the solutions to the questions and activities proposed by each group member.
- Agreement on common questions/queries and their resolution with the teacher's help.
- To produce a report with a group global solution (deliverable 1).

3.2. Pacification of the experimental work

Self-work outside the classroom:

- Assignment of an equipment and variables to be verified to each member of the team.
- Detailed resolution of questions related to the equipment maintenance and specific verification and/or calibration instructions recommended by the manufacturer.

Group work in the classroom (base group meeting):

- Expert meeting.
- Discussion on what needs to be done to perform the verification of each HPLC equipment module.
- Comparison and resolution of questions/doubts.

Group work outside the classroom (base group):



- Each group member explains to whole team the specific information discussed at the meeting of experts.
- Verification and confirmation that all group members know all the tasks needed to make the overall verification of the HPLC.
- Planning the tasks to be performed at the laboratory. Drafting of a working procedure in which the necessary materials and steps for conducting the experimental work are thoroughly specified (deliverable 2).

3.3. Execution of the experimental work

Group work in the classroom (base group):

- Checking the suitability of the required material and solutions to carried out the planned work.
- Performing the planned steps for the equipment verification.
- Data collection.

Group work outside the classroom (base group):

- Data treatment.
- Drafting the verification report and certify.

3.4. Evaluation

In order to determine the learning process, individual and group learning are evaluated. Individual learning is evaluated with a written test which comprises multiple-choice questions and small open questions. Furthermore, the group performance is assessed by the documents (deliverables) submitted during and after practice sessions.

4. Evaluation of cooperative learning process.

4.1. Identification and assessment of deficiencies and opportunities for improvement.

At the end of each part (previous tasks, planning and planning and execution of the experimental wok), each student individually filled out a questionnaire designed to



reflect on individual and group work, and to highlight difficulties that may emerge during the practical sessions. In this case we have chosen a questionnaire similar to the one used by Putnam (1993) and adapted by Pujolàs (2003), in which students indicate their degree of satisfaction indicated with different items related to the group work, such as i) the degree of completion of individual/group assigned tasks, ii) degree of successful use of the available time, both in meetings and for tasks development, iii) learning progress of each group member, iv) degree common team goals achievement, v) degree of compliance of each team member personal commitments and vi) individual reflection on what the group does well and what the group should improve.

5. Conclusions

In the cooperative learning organization system, students are split up in teams to carry out an specific task. As individual success depends on the group success as a whole, students are not only of their own learning but also of their group mates learning.

We believe that this active learning methodology is an effective alternative to traditional teaching methods (in which the protagonist is the lecturer). With the application of this methodology laboratory class of chemical analysis, we intend to remove the laboratory guide book, which normally are similar to a cookbook. With the use of this guide books students usually just follows a well-established procedure (recipe). In this way we increase the involvement and motivation of students in the laboratory practice and experimental work to be carried out.

Cooperative learning methodology also enables also the development of other skills and competences such as responsibility of the own-learning, team-working, critical thinking, project management, negotiation techniques, argumentation and communication among others. In short, we believe that this methodology link students to the labour market, more efficiently than traditional methodologies, and therefore also increases their employability.

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