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INTRODUCTION OF TEAM SELF-REGULATION FOR TEAMWORK PROMOTION. A CASE STUDY IN ENERGY ENGINEERING TOPICS

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Abstract

The learning and development of teamwork skill is only possible if its achievement is a self-building process of the student. In turn, the teachers must become guides in the process of a learning which is not limited only to the topic of their own course, but which must be imbedded with a good dose of this skill. Promotion of teamwork is not spontaneous but very often requires the use of self-regulation within teams. The aim of the paper is to elucidate if positive or negative self-regulation of teams are useful to promote teamwork. The paper presents some experiences on the use of self-regulation of teams within active teaching strategies that involve teamwork as a critical skill in engineering education. The paper presents first the fundamentals of the learning strategy adopted, intended to develop teamwork abilities in the students. It then describes the context and challenges faced up in the case studies, as well as the essentials of the learning activities proposed. Finally, the paper discusses the student's achievement and perception. Although some influence of unbalanced teams there exists, it can be stated that positive self-regulation of teams is more easily accepted by teams than the negative ones, because of the influence on interpersonal relationships amongst students. The topics involved in this experience are energy related topics such as electrical installations, heat transfer, engineering thermodynamics or theory of circuits.

Keywords – teamwork, engineering education, energy

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1 INTRODUCTION

Rapidly changing technology means that graduates of engineering programs need to acquire important qualities of lifelong learning and self-learning to support a through-life ability to respond to advances in technology. Amongst them we could mention skills such as teamwork, creative thinking, communication or critical self-awareness. The industry (Buonopane, 1997) demands and expects from engineers a wide range of these generic skills in addition to a high degree of technical competence. Also, some engineering institutions and associations (ABET, 2012; Grinter, 1995) include this appreciation in their reports. The learning and development of these skills is only possible if, as much as the scientific knowledge, their achievement is a self-building process of the student. In turn, the teachers must become guides in the process of a learning which is not limited only to the topic of their own course, but which must be imbedded with a good dose of these skills.

The literature in general education, technical education, and educational psychology is replete with methods that have been shown to facilitate learning more effectively than the traditional single-discipline lecturing approach. However, instructional methods for engineering education should meet some specific criteria to be chosen as effective methods (Felder, Woods, Stice & Rugarcia, 2000). First, much of the basic content of engineering courses is not a matter of opinion. Though many innovative instructional methods have been developed for nontechnical courses and emphasize free discussion and expressions of student opinions, with minimal teacher-centered presentation of information, such methods that emphasize process exclusively to the detriment of content will not be considered. Second, the instructional methods should be able to be implemented in regular classrooms and laboratories with no tools or devices beyond those routinely available to all engineering instructors (for example, a very expensive workstations network or experimental devices). Third, most engineering professors should feel reasonably comfortable with the instructional method after a little practice. And fourth, the methods should be consistent with results of theoretical and/or empirical studies in the cognitive and educational psychology literature, and they should have been implemented successively in engineering classes by independent investigators. Articles by professors who have tried new methods and written about the results with the only evidence on its behalf and personal testimony should not be considered.

This paper focuses on teamwork. Teamwork is the student outcome that means the ability to function on multidisciplinary teams. Teamwork is one of the most frequent ability involved in recent engineering courses, and takes part of many student-based approaches to learning, such as active methods, cooperative learning or problem based learning. However, promotion of teamwork is not spontaneous but very often requires the use of self-regulation within teams. The aim of the paper is to elucidate if positive or negative self-regulation of teams are useful to promote teamwork. The paper shows some experiences on the use of self-regulation of teams within active teaching strategies that involve teamwork as a critical skill. The paper presents first the fundamentals of the learning strategy adopted, intended to develop teamwork abilities in the students. It then describes the context and challenges faced up in the case studies, as well as the essentials of the learning activities proposed. Finally, the paper discusses the student's achievement and perception related to the self-regulation mechanisms adopted. The topics involved in this experience are energy related topics such as electrical installations, heat transfer, engineering thermodynamics or theory of circuits, within the several engineering degrees of the University of Burgos, Spain.

2 FUNDAMENTALS OF TEAMWORK AS CRITICAL SKILL IN ENGINEERING EDUCATION

Many lecturers believe that simply giving three or four students something to do together—a laboratory experiment and report, for example,—should somehow enable all of them to develop the skills of leadership, time management, communication, and conflict resolution that characterize high performance teams. Very often, no one of these improvements happen. Under such circumstances, the most frequent is that one or two students do most or all of the work, and all students get the same grade. This does not promote development of teamwork skills.

If promoting teamwork skills is an objective, you could use a structured approach to teamwork like cooperative learning. Cooperative learning is an instructional approach in which students work in teams on a learning task. Following the work of Johnson, Johnson and Smith (1999), the team assignments should be structured to assure positive interdependence (that is, if anyone on the team does not fulfill his or her responsibilities, everyone is penalized in some manner), individual accountability for all the work done on the project, face-to-face interaction (at least part of the time), development and appropriate use of interpersonal skills, and regular self-assessment of team functioning. Under this approach, only one problem set or report is handed in by a group and one group grade is assigned to the project, but adjustments for individual team citizenship (or lack thereof) can and should be made.

Some suggestions to help lecturers to implement cooperative learning and teamwork could be found in refs. (Felder et al., 2000; Johnson et al., 1999; Woods, Felder, Rugarcia & Stice, 2000; Felder & Brent, 1994; Felder, 1995; Heller, Keith & Anderson, 1992; Kaufman, Felder & Fuller, 2000). Amongst them, we can find the following concerning this paper:

- Explain to students what you are doing and why. Some students regard teamwork as a game the instructor is playing at their expense, and some may complain that the instructor is not doing his/her job (which they see as lecturing to them on everything they will need to know for the tests). Twenty minutes on the first day spent giving some of the reasons for using the approach (e.g., it prepares students to function in the environment in which engineers work) can go a long way toward overcoming the resistance.

- Assign some or all teamwork to teams of 3-4 students. In teams of two, one person tends to dominate and there is usually no good mechanism for resolving disputes, and in teams of five or more someone is usually left out of the process. Collect one assignment per group.
- Promote positive interdependence. Assign roles, for example, the manager (organizes the assignment into subtasks, allocates responsibilities, and keeps the group on task). Other suggested roles are the recorder (writes the final report or problem solution set, or for large projects, assembles the report), and the checker (proofreads and corrects the final report before it is submitted). Randomly select one member of each group to present a problem solution or report on a specific aspect of the project and give everyone in the group the grade earned by that individual. If you use the last strategy (which also promotes individual accountability), tell the students well in advance that you plan on doing so but do not provide much advance notice of which students will present on which parts of the assignment.
- Promote individual accountability. Give primarily individual tests (although not necessarily all of them —especially if the groups are heterogeneous in ability; some pair or group testing promotes positive interdependence). Call randomly on individual group members to present their group's results. Use peer assessment to adjust team grades for individual effort and/or citizenship.
- Start small and build. If you have never used cooperative learning and you are not working with a colleague who is experienced in this approach, you might consider beginning on a relatively small scale, with several assignments done by groups and the rest done individually. Once you begin to gain confidence, increase the level of your involvement to a point that feels comfortable to you. When problems arise, remember to consult references on cooperative learning for ideas about how to deal with them.

Successful implementation of these suggestions could strongly depend on the instructor's confidence, but also on the cultural and educational background of the respective institution. Introduction of active teaching strategies could differ from one country to another, and is very influenced by tradition in teaching practices.

3 THE CASE STUDY: APPLICATION OF ACTIVE LEARNING AND TEAMWORK APPROACH IN ENERGY ENGINEERING TOPICS

The experiences described in next paragraphs have been developed in topics belonging the third and fourth semesters of an eight-semester undergraduate program leading to a degree in Electronics and Control Engineering at the Higher Polytechnic School of the University of Burgos (Spain), as shown in Table 1 (This undergraduate program is the transformation of the previous one to the recent Bologna scheme). The set of first to fourth semesters are devoted to basic engineering sciences, and they are the same in any of the engineering degrees related to industry concerns (mechanics, electronics, control, industrial management, etc.) at the University of Burgos. The aim is to give deep foundations in basic engineering sciences to allow the engineer to adapt to changing roles along his working life. All the modules are taught over a period of 14 weeks and involve four hours of timetable contact per week (2 classroom/theory hours, 2 seminar/laboratory hours), for a total workload of 6 ECTS credits. It can be observed that some of the subjects involved in these basic engineering sciences are related to energy topics, in a broad sense, such as Engineering Thermodynamics, Fluid Mechanics Engineering, Electrical Engineering Fundamentals or Theory of Circuits. Some of the respective teachers belong to an innovation teaching group and collaborate frequently in implementing innovative teaching-learning experiences.

As designed in the study plan, the students should acquire some general skills as those described in the Introduction section (http://www.ubu.es/titulaciones/es/grado_electronica). Amongst these skills is the teamwork skill. This skill is assigned to most of the subjects of the study plan. However, the implementation of this skill is unbalanced, frequently limited to the aforementioned simple idea of giving three or four students something to do together.

The case study presented here shows the results of the adoption of self-regulation mechanisms for the promotion of teamwork, within the frame of a collaborative approach. The objective is to compare the benefits and pitfalls of the two alternative self-regulation methods used, that can serve as an example for those teachers interested in using the same approach. Two cases of application would be described, in the subjects of Theory of Circuits and Engineering Thermodynamics, respectively, as well as some additional similar experiences developed by the same teachers in other subjects.

First Year			
1st semester	***ECTS credits***	***2nd semester***	***ECTS credits***
Physics I	*6*	*Physics II*	*6*
Mathematics I	*6*	*Mathematics III*	*6*
Mathematics II	*6*	*Chemistry*	*6*
Technical Drawing	*6*	*Materials Science*	*6*
Computers I	*6*	*Economics*	*6*
Second Year			
3rd semester	***ECTS credits***	***4th semester***	***ECTS credits***
Engineering Thermodynamics	*6*	*Fluid Mechanics Engineering*	*6*
Statistics	*6*	*Electronics Fundamentals*	*6*
Electrical Engineering Fundamentals	*6*	*Mechanic*	*6*
Production Management	*6*	*Theory of Circuits*	*6*
Elasticity and Strength of Materials	*6*	*Automation & Industrial Control*	*6*
Third Year			
5th semester	***ECTS credits***	***6th semester***	***ECTS credits***
Electrical Machines	*6*	*Power Electronics*	*6*
Regulation & Control	*6*	*Microprocessor Systems*	*6*
Digital Electronics	*6*	*Electronics Instrumentation*	*6*
Analogical Electronics	*6*	*Industrial Automation*	*6*
Electronics Technology	*6*	*Production and Manufacturing Systems*	*6*
Fourth Year			
7th semester	***ECTS credits***	***8th semester***	***ECTS credits***
Computers II	*6*	*Industrial Automation*	*6*
Technical Projects	*6*	*Industrial Robotics*	*6*
Optional Module I	*6*	*Final Project*	*18*
Optional Module II	*6*		
Optional Module III	*6*		

Table 1. Electronics and Control Engineering Degree at the University of Burgos

Several of the recommended rules cited in the previous section have been followed from the very first initial experience:

- Each teacher has chosen his or her respective confidence level of application of the teamwork approach.
- The teachers have taken benefit of some previous experiences on active learning (Montero & González, 2009; Sáiz, Montero, Bol & Carbonero, 2012).
- Teams of 3-4 students have been used.
- Each member of the team gets the same grade for every task assigned to the team, but internal adjustments for individual team citizenship can be made.

4 RESULTS AND DISCUSSION

The first set of experiences was performed in the period 2004-2010, in the previous study plan, degree in Electronics Engineering (3 year degree, six semesters). At this time, explicit declaration of general skill was not compulsory, and the development of such skills depended on the teacher's engagement. The first topic involved was Electrical Installations (optional, 3rd year), involving an average of 15 students. The teaching method adopted was the problem based learning approach. Teams of 3 to 4 students were proposed to design an industrial electrical network. Concerning assessment, 60% of grade was assigned to teamwork, while 40% was assigned to individual examination. Teams were constituted by the students themselves, without teacher decision.

Moreover, a problem based learning approach was also used to teach the topic Introduction to Heat Transfer (compulsory, 1st year), as described in reference (Montero & González, 2009). The average group was of 50 students. The open problem proposed was the design of a heat sink for heat dissipation in a power electronic device. The grade, till 75% (25% partial designs + 50% final design), was assigned to teams of students formed by 4 students, while the rest 25% were individual exams.

Amongst other skills, a survey of the teamwork developed in every topic was performed during the period 2004-2010, basically by means of questionnaires posed to students and the perception of the teachers collected in a checklist. Table 2 shows some of the results. The perception questionnaires (scale from 1 to 5, ranging from 1 “strongly disagree” to 2 “strongly agree”) included the statement “Learning through teamwork is a better way to learn than on my own”. Along the period considered, teamwork was recognized as the most valuable characteristic of the sessions, resulting in an average perception within the interval 4.0-4.2, being less than 3% the fraction of students in disagreement. The results, in both 1st and 3rd year, were very similar, and the students felt that teamwork improved their learning.

Question	***Electrical Installations, 3rd year, 15 students Agreement (1 min – 5 max)***	***Heat Transfer 1st year, 50 students Agreement (1 min – 5 max)***
Learning through teamwork is a better way to learn than on my own	*4,0*	*4,2*
I have learned more through group discussions than I would have if these had never taken place at all	*3,0*	*4,0*
I listened carefully to the statements and proposals made by others during the group discussions	---	*4.0*

Table 2. Student’s perception about teamwork skill

As the students produced public presentation and discussion of their works, the questionnaire also presented the statement “I have learned more through group discussions than I would have if these had never taken place at all”. In the topic of Electrical Installations the average answer was graded 3.0, with almost no dispersion, while in the Heat Transfer topic the same was 4.0, with modal agreement of 70%. Some explanation found by the teachers is the fact that while 1st year appreciate more the learning by teams interaction, 3rd year students were more mature and worried about finishing their studies

Finally, although the critical attitude of students towards others classmates in the groups is variable, teamwork was recognized by 1st year students as being of great value in the sessions in improving relational skills (“I listened carefully to the statements and proposals made by others during the group discussions”, average value 4.0, 70% global agreement)

Concerning the perceptions of the teachers on teamwork, the difficulties found in Electrical Installations with respect to the engagement and participation of each team member (“parasite” students) were very scarce and they were solved by means of direct action of the teacher. In the Heat Transfer topic, if those problems existed, they were not detected by the teacher. In both cases, individual exams allowed to differentiate the grade amongst member teams.

With respect to the comparison of final grades obtained by the students, only general data were reported in the pre-bologna previous work (Montero & González, 2009). Bad marks decreased dramatically when change from traditional lecturing to problem based approach took place, but no analysis on the influence of teamwork skill in the improved grading could be performed.

During the period 2010-2013, the University of Burgos has produced the transformation from old degrees to the new degree in Electronics and Control Engineering, within the frame of Spanish adaptation to the European Higher Education Area (EHEA), launched along with the Bologna Process, and to the European Credit Transfer Systems ECTS. The transformation concerned not only the program of contents but also involved a deep change in the teaching-learning approach. Some of the most relevant differences between the previous and the new study plan are shown in Table 3. When producing this transformation, the teamwork skill was involved to mostly all topics. The full set of scientific and general skills of the degree are now scheduled and declared, following the requirements of accreditation of the Spanish Ministry of Education. The authors then decided to take advantage of their previous experiences, but taking into consideration some of the recommendations presented in the section 2 of this paper.

Pre-Bologna study plan Degree in Electronics Engineering (1999)	***Bologna Study plan Degree in Electronics and Control Engineering (2010)***
The credit system was based on the teacher (1 credit= 10 lecture hours)	*The credit system is based on the student (1 ECTS = 25 hours of student workload)*
Skill development was not compulsory nor systematic (depending on the teacher's aims)	*Skill development is systematic and within the frame of the degree's competence design (accredited by external agency)*
Assessment was focused mainly in the scientific contents (written examinations, laboratory reports, etc.)	*Assessment involves skill outcomes as well as scientific contents.*
Assessment was conceived only as a method for grading students	*Assessment is conceived not only for grading students but also as a useful feedback for self-assessment and learning*

Table 3. Comparison, concerning skill development, between the pre-Bologna and the Bologna degree in Electronics Engineering at the University of Burgos

Thus, in the topic Theory of Circuits, the development of the activities of the students and its evaluation are distributed amongst individuals exams along the course (30%), final individual exam (40%) and team laboratory practice (30%). This last activity involves the laboratory work (sine stationary circuits, three-phase systems, etc.), the writing of laboratory reports and team-exams. We can say that the approach of the topic is a traditional one, based on individual learning by means of lectures and exams, while the teamwork plays a complementary role, both in workload hours and its assessment (30%). The grade assigned to the team is unique, but there exits an internal self-assessment mechanism that allows the adjustment for individual citizenship. During the academic year 1011-12, with 50 students participant, the team-exams was the novelty added to the common laboratory work and the corresponding reports of the team assessment. The realization of team-exams was intended to check the engagement of every member of the team, and the internal organization skill. When an exam has to be performed by a team of 4 members, and one or two members keep themselves inactive, not only the scientific quality of the team performance will be harmed but also strong stress among the members could appear. The internal self-regulation mechanism introduced consisted in the use of a multiplier factor, between 0 and 1, to be applied to every member of the team. This self-regulation factor was decided by team agreement. The result in 2011-12 was that all the 17 teams involved decided to apply the factor 1, it is to say no internal adjustment was really applied. When the teams were asked about, the common answer was that "we have to share several years with the same colleagues along the degree, and we do not want to face each other". Faced with this situation, the teacher decided to interview directly every team to check her own perception. After this intervention, 20% of the 17 teams applied a self-regulation factor other than 1 for internal adjustment. During the academic year 2012-13, with 55 students, the same approach was applied, but emphasis was put on explanation of the same to the students from the very beginning. Only 10% of the 18 teams applied the internal adjustment of individual members. Although the self-regulation mechanism for individual adjustment exists, its application in the form of reduction coefficient finds the pitfall of the student's reluctance to face each other with penalty grade, even they recognize that their performance has not been the right one.

In the topic Engineering Thermodynamics, the problem based learning approach was adopted. At the beginning of the course an open problem of industrial energy analysis is assigned to the students, while the teacher plays the role of the senior engineer of the company. The students are asked to carry out a parametric energy analysis of the installation in terms of fuel consumption, energy production and CO_2 emissions, depending on certain range of pressure and temperature of fluids and on the isentropic efficiency of turbine and compressors. The open problem involves all the learning outcomes of the topic and is the frame of all the activities at the classroom and laboratory during the semester (Montero, Alaoui, González & Aguilar, 2012). Three assessment criteria have been proposed: team reports, up to 30%; individual exams, up to 30%; and final team report, up to 40%. Then, it can be stated that the approach is strongly centered on teamwork (70%), while the individual assessment allows differentiation amongst team members. During 2011-12, 12 teams were formed by 47 students. In 2012-13, also 12 teams were formed by 46 students. In both academic years an internal adjustment mechanism was adopted for self-regulation of teams. Extra grade of 1 point (over 10 points grading) could be awarded to any member of the team, by previous agreement of its members. Thus, every team could recognize those members who had developed more and better performance of any of its components. Along 2011-12, 20% of the teams used this improvement and, in 2012-13, 30% of the teams did it. Being an internal, positive self-regulation, no teacher intervention was needed. In the opposite, lack of performance of some teammates and the corresponding conflicts amongst members were not detected by the teacher, if they occurred.

5 CONCLUSIONS

Both case studies presented are devoted to the development of the teamwork skill, accordingly to the recommendations of the accreditation of engineering education programs. To get it, some of the basic recommendations on the topic of learning in engineering found in the literature have been followed. More precisely, emphasis has been put on the explanation to students of the importance of this skill in his professional development. Teams of 3-4 members have been constituted, and internal interdependence has been promoted amongst teammates. Team work has been used to the limit that every teacher has considered adequate to reach the learning outcomes of the subject and its own experience. These criteria have been applied to topics on energy content, one electrical and the other thermal, within the graduate program on Electronics and Control Engineering.

The teams formed were stable during the semester. After the initial period of mutual knowledge, the teams have improved their performance. However, as the teams were constituted directly by student's choice, with no teacher decision, some unbalanced teams could appear (teams of friends, teams of the most capable students, etc.). It could be a good option to consider the teacher to assign the teams after a preliminary test, to set heterogeneous teams instead of homogeneous teams. In both topics presented only one grade was assigned to each team and task, although an internal self-regulation mechanism have been used to adjust individual performance. Individual exams have allowed us to set differences in the scientific learning. The peer assessments amongst members to adjust individual accountability of those teammates who have better performance have been used in two ways: (i) by means of a reduction factor; (ii) by means of an extra linear grade of 1 point. The team use of every type of self-regulation has been 15% for the first one (reduction factor) and 25% for the second (extra grade). Although some influence of unbalanced teams could be considered, it can be stated that positive self-regulation of teams is more easily accepted by teams than the negative ones, because of the influence on interpersonal relationships amongst students. In the opposite, the positive self-regulation mechanisms could hide bad effects due to inactive students that harm the team performance.

Other aspect that can be improved is the promotion of team internal organization, mostly when teamwork is takes the greater fraction of activities and assessment, for example 70% in Engineering Thermodynamics. In this case during the course 2012-13, the teacher has assigned a coordinator in every team, with the aim of keeping the group on task. However, the monitoring task of the teacher with the 12 coordinators was low-intensity and the results were of poor value. Nevertheless, it is considered as a future improvement to teamwork skill development.

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