New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION
Edition 4

Teamwork Development in Heat Engines Sciences by Means of a Rubric-based Method

Fernando Aguilar[1], María Jesús González-Fernández[2], Eduardo Montero[3]
Department of Electromechanical Engineering, Escuela Politécnica Superior, Universidad de Burgos (Spain)
[1]faguilar@ubu.es, [2]mjgf@ubu.es, [3]emontero@ubu.es

Abstract
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. At present, most of science and/or engineering programs at high schools and universities describe what the students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program to prepare graduates to attain the program educational objectives. The industry demands and expects from engineers a wide range of these generic skills in addition to a high degree of technical competence. This paper focuses on teamwork skill. 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. The learning and development of teamwork is only possible if, as much as the scientific knowledge, their achievement is a self-building process of the student. The aim of the paper is to check if the use of rubrics for teamwork assessment is a useful method in terms of easiness and short time of application, and alignment with the active teaching approach adopted. A set of 51 Mechanical Engineering students were involved, during the fall semester of 2014, in the experience of developing a simulator of power plant with the Engineering Equation Solver™ software, EES. The power plant is a pulverized coal fired combined heat and power (CHP) plant. A term paper assignment was given to students, organized in teams of three members. The expected outcomes are the ability to perform the technical analysis of the power plant station in terms of mass and energy balances in different modes of work, and the development of personal skills such as data collection and analysis, problem-solving, critical thinking, teamwork, autonomous learning and the ability to apply theoretical knowledge to practice. A rubric was developed, intended to assess teamwork skill, with the requisite of being easy to understand by the students and short time consuming to fulfill it. Correlation between skill development and final team performance and grading is presented. The paper could be of interest to those readers that want to promote skill development in other science courses.

1. Introduction
Engineering institutions and associations [1, 2] declare in their reports the relevance of including a wide range of generic skills such as teamwork, creative thinking, communication or critical self-awareness, in addition to a high degree of technical competence, in the engineering curricula. The same has happened within the Bologna transformation of European curricula in recent years. 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.
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. But cognitive skills, such as teamwork, are difficult to measure with a conventional "test", graded for correct versus incorrect answers. However, a rubric can allow characterizations of student thinking or understanding. A rubric is an assessment tool that identifies features that student work should have, along with several levels of quality of student work that might be associated with each feature. The aim of the paper is to check if the use of rubrics for teamwork assessment is a useful method in terms of easiness and short time of application, and alignment with the active

teaching approach adopted. A problem-based learning (PBL) approach was used to lead the learning process of the students.

2. Rubric-Based Method to Assess Teamwork Skill in Heat Engines Sciences

The experience described in next paragraphs has been developed in science topics belonging to the seventh semester of a four-year, eighth-semester undergraduate program leading to a degree in Mechanical Engineering at the Higher Polytechnic School of the University of Burgos (Spain), as shown in (http://www.ubu.es/es/english-information/the-international-office/ects-guide-academic-courses-on-offer-and-application-forms/course-catalogue-2014-2015/new-degrees-adapted-to-the-ehea-european-higher-education-a).

In the topic “Heat Engines” (compulsory, 4th year, 7th semester), a structured problem based learning approach was adopted. This compulsory module aims to impart a fundamental knowledge on heat engines and stationary power stations, with a special focus on energy efficiency analysis. At the beginning of the course an open problem of a power station energy analysis is assigned to the students, following the PBL approach. The students are asked to carry out a energy analysis of the installation of the conversion of an old power station using coal to a modern one which could use coal and solid biomass fuels alternatively in terms of fuel consumption, energy production and CO2 emissions. Students could use some software to perform the simulation of the power station, most of them using the Engineering Equation Solver™ software, EES [3]. 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. Students are committed to prepare a report on the specific problem on energy analysis, to be ready after a period of five months.

Previous works of the authors deal with self-regulation of teamwork [4]. This work deals with teamwork skill development and continues previous studies of the research team in the same field [5]. There exist several literature references on the use of rubrics in engineering education [6-8]. The authors developed a rubric to evaluate five elements of team work: (1) Contribution to teamwork; (2) Taking responsibility; (3) Individual contribution outside of team meetings; (4) Promotion of constructive team climate; (5) Response to conflict. The rubric is presented in Table 1.

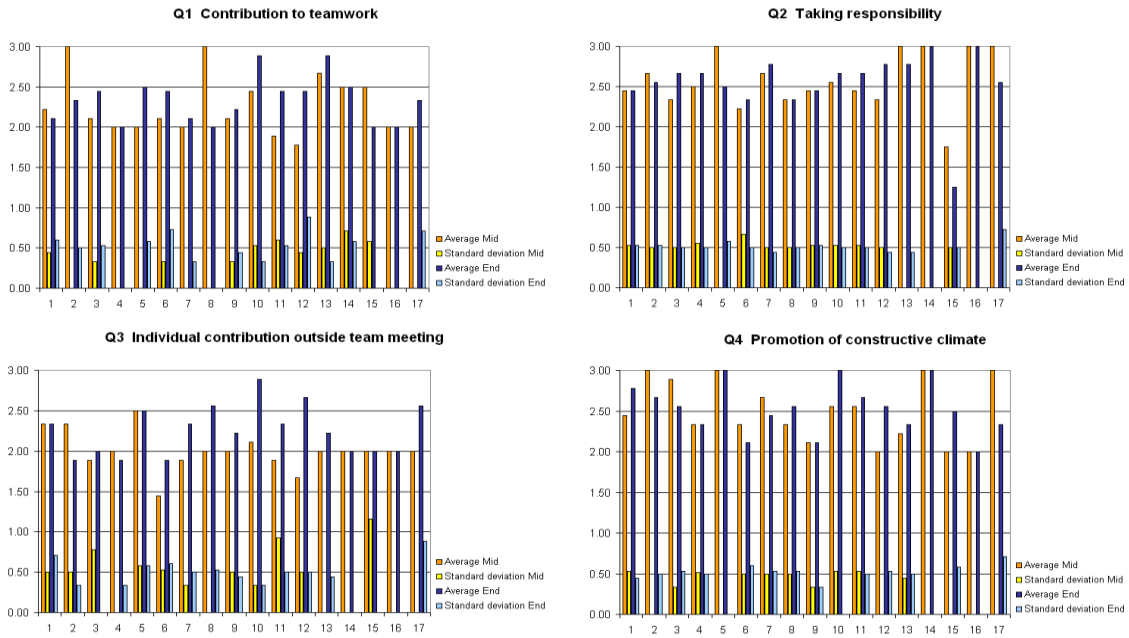
Definition: Teamwork is behaviors under the control of individual team members (effort they put into team tasks, their manner of interacting with others on team, and the quantity and quality of contributions they make to team discussions.)				
Instructions: Please rate YOURSELF & YOUR TEAM MEMBERS using the provided table. Please fill in the table below honestly, and as accurately as possible. Please use the following rating scale: 3-Excellent; 2-Good; 1-Needs improvement; 0-Unacceptable				
1 Contribution to teamwork				
Level	**Description**	**Member 1**	**Member 2**	**Member 3**
3	Collect and present to the team a great deal of relevant information; offer well-developed and clearly expressed ideas directly related to the group's purpose			
2	Collect basic, useful information related to the project and occasionally offer useful ideas to meet the team's needs.			
1	Collect information when asked for and try to offer some ideas, but they are not well developed, or not clearly expressed, to meet team's needs.			
0	Fail to collect any relevant information or give useful suggestions to address team's needs.			
2 Taking responsibility				
3	Perform all assigned tasks very effectively, attend all team meetings, participate enthusiastically, and remain very reliable.			
2	Perform all assigned tasks, attend team meetings regularly, and usually participate effectively and reliably.			
1	Perform assigned tasks but needs many reminders, attend meetings regularly but generally do not say anything constructive, or eventually expect others to do his/her work.			
0	Fail to perform assigned tasks, often miss meetings, do not have any cons-tructive contribution when present, or usually rely on others to do the work.			
3 Individual contribution outside of team meetings				
3	Completes all assigned tasks by deadline; work accomplished is thorough, comprehensive, and advances the project. Proactively helps other team members complete their assigned tasks to a similar level of excellence.			
2	Completes all assigned tasks by deadline; work accomplished is thorough, comprehensive, and advances the project.			
1	Completes all assigned tasks by deadline.			

0	Frequently, does not complete the assigned tasks by deadline			
4 Promotion of constructive team climate				
3	Always listen to others and their ideas, help them develop their ideas while giving them full credit, and always help the team to reach a fair decision.			
2	Generally listen to others' points of view, always use appropriate and respectful language, and try to make a definite effort to understand others.			
1	Usually do much of the talking, do not pay much attention when others talk, but avoid personal attacks and put-downs although sometimes patronizing.			
0	Often argue with team mates, do not let anyone else talk, have occasional personal attacks and "put-downs", want to have things done his/her way, or do not listen to alternate approaches.			
5 Response to conflict				
3	Addresses destructive conflict directly and constructively, helping to manage/resolve it in a way that strengthens overall team cohesiveness and future effectiveness.			
2	Identifies and acknowledges conflict and stays engaged with it.			
1	Redirecting focus toward common ground, toward task at hand (away from conflict).			
0	Passively accepts alternate viewpoints/ideas/opinions. Doesn't accept confict solving			

Table 1. Rubric for ability to function in teams

3. Discussion and Conclusions

During the academic year 2014/2015, the study module has been being taught using the aforementioned structured PBL approach. A total of 51 students participated. Student attitudes and perceptions to this assessment approach were surveyed through the rubric shown in Table 1. The rubric was presented to the same set of students in two separate periods: the first one after two months of lecturing (called the “Mid” rubric), and the second at the end of the semester (called the “End” rubric). Every team member filled the rubric evaluating himself and the rest of members. Distribution of respective values for the 17 teams is presented in Figure 1.



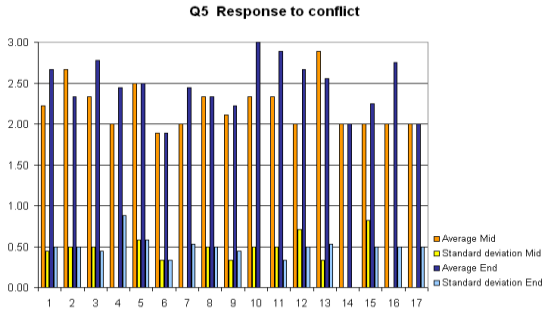


Figure 1. Average and standard deviation of answers to questions 1 to 5 for every team.

The following analysis is related to the End rubric. Concerning question 1, contribution to teamwork, the average score for the whole set of teams is 2.33, with a standard deviation of 0.42. Minimum scoring is 2.00 for teams 8, 15 and 16, while maximum is 2.89 for teams 10 and 13. That mean, that, at average, the members contribute fairly to the teamwork, but with some exceptions. With respect to individuals, only two students received a score less of 2.0 in this category, which means a poor contribution for only 2 students from a set of 51. On the counterpart, 5 students received the maximum score of 3.0.

Related to question 2, taking responsibility, the average score for the full group is 2.55 (the highest of the rubric), with standard deviation of 0.45 (also the highest one in the rubric). All the teams performed over 2.33, with the only exception of team 15 (1.25) and the maximum is 3.00. Then, students were responsible in a very god manner in all the teams. Twelve students received the maximum score 3.0, while only two students received less of 2.0 and the lowest was 1.0 for one student.

Question 3 referred to individual contribution outside team meetings, it is to say, homework. Average value for this question is the lowest one of the rubric, 2.25 , standard deviation being 0.39 (the lowest of the rubric). Though it is not a bad value, it shows the weakest feature of teams. Five students received the maximum 3.0 in this category, each belonging to different teams. It seems these students made an extra contribution to teamwork with respect their colleagues. In the opposite, one student scored 1.3 and four scored 1.7, showing also this lazy behaviour at the same time. Only one team got an average of 2.89, very good performance in this category.

Question 4 deals with promotion of constructive team climate. This question obtained an average valuation of 2.53 and a standard deviation of 0.40. It means that high level performance of the teams in this topic, with moderate agreement. All the teams performed better than 2.11. Three teams had three members with 3.00, which shows also high performance in this category.

Response to conflict was the topic of question 5. The average value is 2.44, with standard deviation 0.44, showing a fair ability to solve internal conflicts. Maximum value was 3.00 (team 10), while the lowest was 1.89. Nine students received the maximum 3.0, while three of them were in the same team. Only two students got 1.7.

Team 10 got the best scoring in almost all the five categories, average 2.89, with standard deviation 0.23. Categories values range from 2.7 to 3.0, which demonstrate high performance in teamwork skill.

We can conclude that students got a fair performance on teamwork competence. Global average (involving all students and categories) is 2.42, standard deviation 0.42. The students declared the best performance concerning the fact of taking responsibility, probably due to the fact that they were very interested in the topic or, at least, in passing the course. The weakest performance is the contribution of homework. Many reasons could influence this performance, as competition with homework of other subjects

Another interesting concern is the evolution of student's perception on their teamwork along the course. Figure 2 shows the deviation between the End rubric and the Mid rubric for every category for the whole set of teams.

In relation to Question 1, contribution to teamwork, the increase in the average value is very small 0.08, from the Mid to the End rubric, though the positive variation in the standard deviation is quite high, 0.134. This is due to the influence of the huge change of perception of some teams (6 teams present a variation equal or higher than 0.50, even team 8 reflects a variation of 1.00). Due to this result, no solid conclusion can be stated for this category.

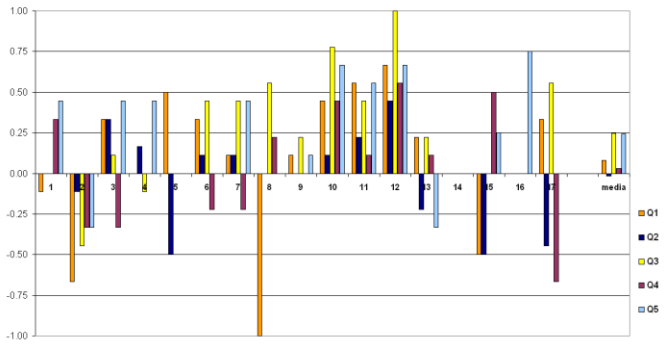


Figure 2. Average deviations of answers to End Rubric with respect to Mid rubric, to questions 1 to 5 for every team.

Question 2, taking responsibility, shows deviation close to zero (-0.02), with low dispersion of the change. The same occurs for Question 4, promotion of constructive team climate (average change 0.03). Students have not changed significantly their perception in these categories.
Concerning Question 3, individual contribution outside team meetings, the average change is the highest one, 0.25, while the standard deviation keeps almost the same value (change of 0.002). The, the students feel as they have increased their commitment with the team.
Finally, Question 5, response to conflict, shows a trend similar to Question 4. The average perception changes from 2.21 to 2.45, a positive increase of 0.24. That means that the potential conflicts amongst team members, if existed, were faced up and solved at the very beginning of the task, allowing a better performance since then.
Finally, with respect to the utility and easy-of-use of the rubric, students show no query about it, all students fulfilled it. It took no more than 4 minutes to keep it. Teacher's perception is that results cover sufficiently the scope of the competence as defined by the institution, and that no more complexity is needed to measure this critical skill.

Acknowledgement

The authors thank the Vicerrectorado de Profesorado of the Universidad de Burgos, for the funding of this project within its Educational Innovation Program, 2013-2014.

References

[1] ABET, Criteria for accrediting engineering programs, Baltimore: Accreditation Board for Engineering and Technology, 2012.
[2] Grinter, L., Report on evaluation of engineering education, Washington D.C.: American Society for Engineering Education, 1995.
[3] F-Chart Software, LLC, http://www.fchart.com/ees/
[4] González-Fernández, M. J, Sáiz-Manzanares, M. C., Alaoui, F. E. M., Aguilar, F., Meneses, J., Montero, E., Introduction of Team Self-Regulation for Teamwork Promotion. A Case Study in Energy Engineering Topics, Journal of Technology and Science Education 3 (2013) 139-147.
[5] González-Fernández, M. J., García Alonso, J. M., Montero, E. The Use of Rubric-Based Method to Assess Teamwork Skill Development. A Case Study in Science and Engineering Courses. Proceedings of 3rd International Conference New Perspectives in Science Education, 2014 (Florence, Italy, 20-21 March 2014).
[6] Martínez, F., Herrero, L. C., de Pablo, S., Project-Based Learning and Rubrics in the Teaching of Power Supplies and Photovoltaic Electricity, IEEE Transactions on Education, 54 (2011) 87-96.
[7] Al-Bahi, A. M., Taha, M. A., Turkmen, N., Assessment of Engineering Professional Skills, Proceedings of IEEE Education Engineering- Global Engineering Education Conference EDUCON 2013, (Berlin, Germany, 13-15 March 2013).
[8] Delgado, M. A., Fonseca-Mora, M. C., The use of co-operative work and rubrics to develop competences, Education for Chemical Engineers 5 (2010) 33–39.