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TEACHERS' WORKLOAD IN A PROJECT-LED ENGINEERING EDUCATION APPROACH

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ABSTRACT
This paper presents a detailed list of activities, carried out by a team of teachers, while organizing and running an Interdisciplinary Project-Led Education (PLE) methodology for a full semester. The study was undertaken at the Engineering School of University of Minho, Portugal. It was based on a first year, first semester of the Integrated Master Degree in Industrial Management and Engineering (IME). The full PLE activities-related workload was accounted on a man-hour basis. Nineteen coordination activities were identified and the respective durations and frequencies were accounted. One semester of IME PLE requires a total of 569 man-hours. The project involved a much greater number of teachers and other staff when compared to a traditional semester. The most time-consuming activities were spotted and strategies and measures to deal with the resulting workload were discussed and some of them are proposed for implementation in future editions of the PLE methodology. Those proposals were considered more efficient ways to rationalize the use of teachers' time.

Keywords: Engineering Education, Project-Led Education (PLE), Teachers Workload

1 INTRODUCTION

This paper presents a detailed accounting of the time spent by a team of teachers carrying out the coordination activities involved in a full semester based on an interdisciplinary Project-Led Education (PLE) methodology. According to Powell and Weenk (2003) in this methodology the teams of students must develop one open project, based on the contents of almost all courses of that semester. The PLE project implies a considerable number of coordination activities, carried out along the semester, namely: weekly planning of project supporting courses (PSC) contents matching project timetable requirements; planning PSC assessment and project assessment; establishing project milestones and deliverables; planning peer evaluation process; providing feedback to team deliverables and project presentations. Although the time spent in some activities is easy to measure (e.g. duration of a tutorial session), other activities' duration depends on each team member (e.g. the analysis and feedback to students' teams can be more or less detailed). The full project workload is subject to analysis

aiming at rationalising coordination team members' time requirements. The coordination team involves teachers from different backgrounds and coming from distinct departments, namely: Industrial Engineering, IT Systems, Mathematics, Chemistry and Education. After engaging in the Bologna process, University of Minho has stimulated the introduction of active learning methodologies in order to improve learning outcomes. The methodology has thereafter re-acquired its fundamental importance. This work is based on the implementation of interdisciplinary projects, ongoing every first year, first semester of the Integrated Master Degree in Industrial Management and Engineering (IME), since 2004/05.

The first year IME Interdisciplinary PLE has been in place for 6 years. This time period is considered sufficient to achieve a mature coordination process. The teachers of the coordination team seem to hold a dual perspective about the overall process. Some claim the time spent on coordinating the full process for a semester is undoubtedly several times higher than the equivalent time required by a traditional teaching methodology. Others do not directly claim an overall time overload, although, they match their own workload peaks during the semester with important PLE deadlines. One of the teachers has decided not to join future editions of the IME interdisciplinary PLE, and the main justification was that of a much higher workload.

Aiming at reducing teachers' workload, without compromising the students learning outcomes, it is necessary to identify where the team effort is directed to, and characterize and measure the correspondent workload. Clarifying the teachers' workload is a key aspect for the evaluation and redesign of the process. The discussion proposed here is centred on the evaluation of the workload aiming to define more efficient ways to enhance PLE organization. The results presented on this paper could also be used to demystify, alert or attract teachers to consider the use of the PLE methodology.

To achieve these objectives, this paper is structured in six sections. The first section introduces the problem, the context and the objectives. The second carries out a brief bibliographic review on PLE methodology, emphasising the workload aspects. The third

section describes the PLE methodology used in the Integrated Master Degree in Industrial Management and Engineering (IME) and the forth section characterizes the teachers' workload and develops the correspondent analysis. Emerging from this analysis, some proposals are presented in the fifth section, in order to try to reduce the teachers' workload. Finally, in the sixth and last section some concluding remarks are outlined.

2 LITERATURE REVIEW

In Higher Education, the teacher is permanently engaged in teaching, research and management activities. Usually the research activities are seen as the most rewarding in terms of academic/scientific recognition and, thus, their importance to teachers is obvious. However, the time conflicting situations between these three kinds of activities occur too often, leading to stress and inefficiency. Consequently, in a large number of cases, the attention paid to teaching activities is clearly insufficient. This puts more demands in the teachers' formation in order to provide them with openness to the change, collaboration skills and ability to understand the learning process as an active, cognitive and constructive process (Simão and Flores, 2007). Additionally, and despite the increased workload, the teacher should have an important role in helping the students so they can develop skills allowing them to have a more active and constructive intervention in their own learning process.

It is a fact that PLE brings to the students a higher workload than the traditional learning methodologies (Lima et al., 2007). These authors have also registered some perceptions where several teachers point out an increase, implied by this learning methodology, on their own workload. However this workload is somehow expectable when switching from traditional learning methodologies to active learning methodologies like the PLE because, normally, these approaches are very different in the way their teachers taught (Stice et al., 2000). This does not mean that teachers embracing traditional methodologies have not a high workload (most teachers have) but this workload is, mainly, associated to the preparation of their own classes. In PLE, beyond this classes' preparation, the teacher belongs to a coordination team with many responsibilities, tasks

and meetings in order to plan, monitor and implement the project. This involves highly complex timetabling issues and scheduling of events with clear deadlines for each element completion. Many teachers are not aware of these aspects and, sometimes, they do not even know the alternatives to the traditional learning methodologies. As referred by Rugarcia et al. (2000), even those teachers who know the alternatives are reluctant to change their teaching methodology because they think that will require a full-time commitment, leaving them with insufficient time to pursue their research.

Additionally, while member of a team, the teacher faces (like his students) all the difficulties that the teamwork involves, namely, conflicting problems with other members (Oakley et al., 2004). Thus the teacher is also involved in a knowledge acquisition process where the need of communication, interaction and team work is fundamental and requires a considerable amount of time and effort to be achieved. This is usually seen by the teachers as a waste of time, which could be otherwise used in research activities. As Felder et al. (2000) point out, this is an obstacle to the adoption of active learning methodologies and demand for the support of the institutions which should valorise the efforts of teachers involved in teaching innovation processes. The teachers have to feel that this work is recognized and will not act as a constraint to their expectations in terms of tenure and promotion.

3 DESCRIPTION OF IME PLE METHODOLOGY

In this case the project aims to integrate four of five courses of first semester of first year of IME degree. The four PSC are “Introduction to Industrial and Management Engineering” (IEGI), “Computer Programming” (PC), “Calculus” (CC) and “General Chemistry” (QG). The project is developed during the entire semester by approximately 40 students in teams of 5 to 7 elements. Each of these teams has a tutor helping to organize their work and develop expected project transversal competencies. It is important to state that students formally receive grades for these courses and the project is a learning task related with all PSCs. Technical support is guaranteed by PSC teachers. So, the project coordination team is composed by project coordinator, PSC

teachers and tutors. For the PLE editions implemented so far, there were 2 to 4 education researchers supporting teachers and students regarding this methodology.

Analysis of the documentation and observation of the process allows the identification of the five main phases illustrated in Figure 1: preparation; setup; start-up; execution; conclusion. The first two phases involves only the teachers while the other three involves both teachers and students.

Figure 1: Project main phases

Two to three months before the beginning of the semester, teachers of PSC start talking about next year project theme. During this preparation phase the evaluation results from last project are consolidated and improvements are planned. Project coordinator is also defined by the IME director.

Setup phase starts at least one month before the semester beginning and is comprised of formal and informal meetings with the following main objectives: project theme definition and specification; milestones definition and planning; project and PSC assessment process definition; project process evaluation definition; project guide elaboration.

Most of the project assessment activities are based on formative activities during the semester. The main impact on project summative assessment is related with a final product assessment. This final product has a 40% impact on students' final grade for each PSC. It can be inferred from this assessment model that project must be firmly grounded on PSC contents, in accordance with PLE methodology. The final product is composed by a written report, prototypes, final presentation and discussion. The final report has a first phase of assessment and feedback, and, in a second phase, the revised final report is also assessed. Nevertheless, along the semester there are several feedback points, where teachers inform the students' teams, sometimes in written forms and others in oral debates, about what should be improved. The assessment of the team project results on a group grade that is individualised in two ways. First there is an intra-

group peer assessment based on transversal competencies. Second there is a written test based on the team project. In parallel with the project assessment process there are also several PSC tasks along the semester. Each PSC teacher strives to guarantee that students achieve the learning outcomes defined for that PSC.

During first week of the semester there is a start-up phase. This phase starts with a project presentation session on the first day. At the end of this session teams of freshman students are formed and tutors are allocated. In the afternoon, teams have formation sessions about team work and public presentations. In the rest of the week teams must develop a mini-project with the following results: create an html web page about project motivation and context; develop a multimedia presentation about those contents and showing how html contents were applied and learned; make a public presentation for colleagues, teachers and department and course directors. This mini-project acts like a simulation of all semester work.

During execution phase there are classes, tutorial meetings, deliveries, and feedback sessions. Each week there are theoretical and project support classes from the responsibility of each PSC. Each tutor has a one hour meeting with his team. Several times during the semester teams have to deliver presentations or reports about the state of their project. These activities have, typically, 10 to 20% impact on project final grade. Furthermore, during this phase there are several summative assessment activities for each PSC. Table 1 represents week 7 to week 10 milestones from 2008/09 project.

Table 1: Milestones of weeks 7 to 10 of 2008/09 project

Milestones	**Week 7**	**Week 8**	**Week 9**	**Week 10**
Courses	IEGI, PC	CC	NSC	QG
Process Evaluation	Individual Reflection			Individual; Team Reflection; Peer Assessment
PLE			Report + Presentation	Feedback session

NSC – Non Supporting Courses

Finally, during the conclusion phase, teams deliver final reports and prototypes. In the last week of the planned project horizon, students have a written test about their team project and teams make the final presentation and discussion.

4 CHARACTERIZATION AND ANALYSIS OF TEACHERS' WORKLOAD

As presented in Section 3, the interdisciplinary PLE project implemented on the first year of IME degree includes four PSCs. Fundamentally, the teachers' workload has two dimensions: D1-type workload - associated to the learning/development of each PSC specific competences (might include learning outcomes not related to the PLE project' contents); and, D2-type workload - associated to the PLE project' management and to the monitoring of team work and project progress.

D1-type workload was less subject to scrutiny, and only the number of items was accounted. Neither the duration of each item nor the total use of time by each PSC were estimated. Therefore D1-type workload is only partially presented, and the results obtained from that data should be regarded as indicative. Table 2 presents the two items subjected to assessment within each of the four PSCs and the respective frequency during the semester. The last column indicates the total number of occurrences of each specific item during the semester (for all PSCs). Considering a 17 week semester, the average number of PSC exams was 0.6 exams per week, while the average number of PSC assignments was 0.7 assignments per week. Thus, and only for PSCs assessment purposes, students had to deliver 1.3 items each week, equivalent to approximately 1 delivery item each 4 days.

Table 2: Assessment items for PSCs (semester basis)

Project Supporting Course Assessment Item	**PSC 1**	**PSC 2**	**PSC 3**	**PSC 4**	**Total**
1. PSC Exam	4	2	2	2	**10**
2. PSC Assignment	1	6	2	3	**12**

D2-type workload was subject to detailed scrutiny. For some specific items (e.g. project guide editing), the time duration estimate was obtained by averaging the individual durations estimates given by the members of the coordination team, while for other items (e.g. tutorial session) the duration is pre-defined.

D2-type workload activities are related to the interdisciplinary project itself. The type of activities conducted were: formal meetings of the project coordination team, tutorial sessions, presentations of student teams, coordinator activities (e.g. updating data and

events on the PLE supporting e-learning tool), conceive and edit documents (e.g. project guide, tutor guide, worksheets for homogeneous grading), students peer evaluation (team), project examination, training on teamwork and multimedia presentation, and finally deliverables' related tasks (checking submission conditions, feedback and grading). Table 3 indicates, for each activity, the corresponding frequency (semester basis), duration and the number of teachers involved.

Table 3: PLE coordination activities, team monitoring and progress assessment

Item	Item frequency (semester based)	Duration (avg. hours)	Lecturers/Tutors /Researchers	Workload (man-hour)
1. Coordination team meetings	10	1	11	110
2. Tutorial sessions	17	1	6	102
3. Extended tutorials	2	2	11	44
4. Training on Teamwork and Multimedia Presentations	2	2	2	8
5. Initial Presentation	1	2	11	22
6. Student teams presentations	2	2	11	44
7. Final student teams presentations	1	5	11	55
8. Coordinator activities	19	2	1	38
9. Project Guide editing	1	1	5	5
10. Peer evaluation sessions	3	1.5	2	9
11. Peer evaluation editing	3	1	2	6
12. Milestones and Deliverables conditions checking	7	1	1	7
13. Deliverable 1 Review (team project management plan)	1	0.5	8	4
14. Deliverable 2 Review and team feedback (Report 1)	1	2	6	12
15. Deliverable 3 Review team feedback (Report 2 - Intermediate)	1	3	7	21
16. Deliverable 4 Review, team feedback and grading (Report 3 - Final Preliminary)	1	6	7	42
17. Deliverable 5 Review and grading (Report 4 - Final)	1	3	7	21
18. Project Examination (individual) and Grading	1	1.5	7	10.5
19. Students Questionaires	1	4	2	8
			Total:	**568.5**
			Avg. Workload per person-week (h):	**2.72**

The project required a total of 568.5 man-hours, distributed by 19 items. Since the coordination team involves 11 people, this value represents a workload of approximately 2 hours and 43 minutes per man-week. The type of work involved in

these activities can be used to build a classification scheme with the purpose to identify the most time consuming classes of activities. There are four project-related classes of activities (A, B, C and D) that represent most of the teachers' workload. Class A is associated with coordination team meetings and ranks 1st with a total of 110 man-hours (item 1). Class B is associated with tutorial sessions and ranks 2nd with a 102 man-hours (item 2); class C is associated with the participation in student teams presentations that ranks 3rd with 99 man-hours (item 6 plus item 7); finally class D is related with reports review, feedback and respective grading ranks 4th with 96 man-hours (item 14 to item 17). When combined these four activities represent 72% of the total time spent by the coordination team members. Figure 2 depicts the workload involved on each activity.

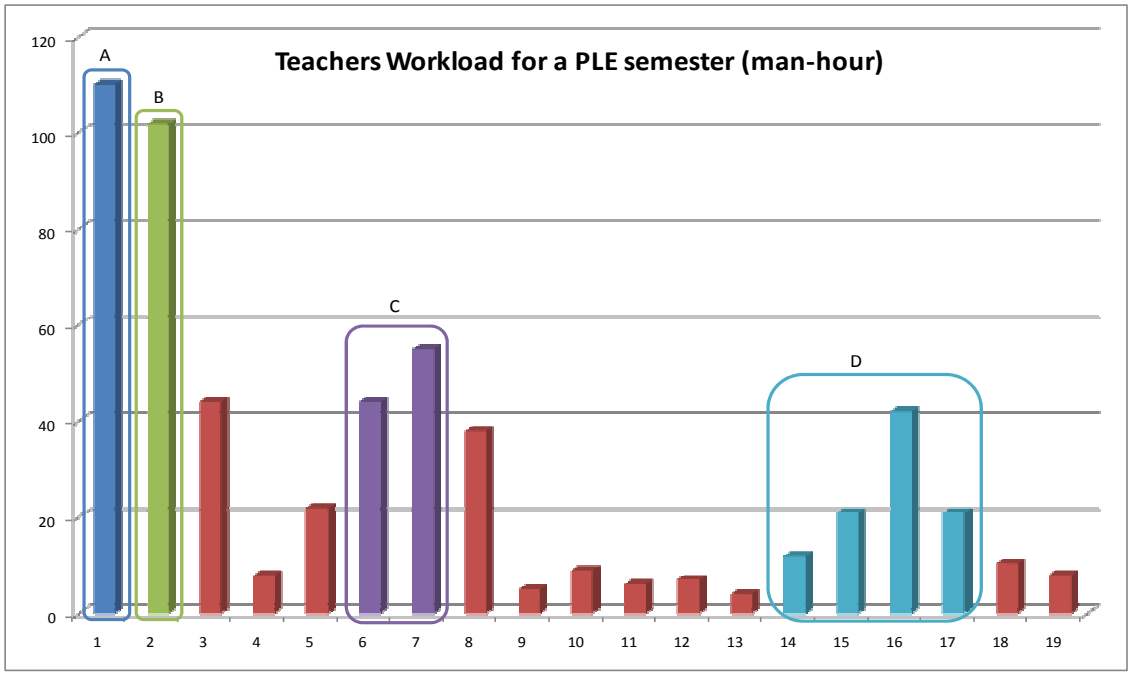

Figure 2: Workload associated to coordination team activities

For project assessment purposes each team of students had to deliver 13 items (presentations, project plan, reports, peer evaluations, individual exam), which represents an average of 0.76 items per week. Thus, globally, students had to deliver approximately 2 items each week (22 PSC related items plus 13 PLE related items, within a 17 week semester).

The data shown in table 3 clearly indicates that the activities requiring the presence of a great proportion of coordination team members, even with short time duration tend to lead to a significant share of global staff time spent on PLE. This is the case of class of activities A (requires 11 teachers), C (requires 11 teachers) and D (requires 7 teachers).

Additionally to these activities there are PSCs lecturing hours. The IME PLE involves PSCs corresponding to 24 ECTS out of 30 ECTS (4 out of 5 Curricular Units - CU). Each semester is considered to have approximately 15 weeks of effective lecturing (20 weeks in total, assessment included) with about 21 hours per week of students to teacher contact. This equates to a weekly global workload of about 27 man-hours for class activities. The number is slightly higher than the standard 21 contact hours, since some classes are given to a fraction of the full class. Therefore two or more teachers can be simultaneously engaged in teaching activities, resulting in a higher man-hour indicator. The effective lecturing time sums up to a global time of 405 man-hours. Additionally, teachers of PSC still have workload associated with teaching, assessment activities and office contact hours that are not analysed in this work. This analysis reinforces the common teachers' perceptions that workload in PLE on the 1st year 1st semester of the IME degree is heavily time consuming when compared to a traditional semester.

However, the authors have realized that some of the staff members do not have a clear perception of this total workload because the number of involved teachers is high. The higher the number of involved teachers, the lower is their perception of the total workload, since the global effort is divided, resulting in less dramatic individual workloads. Additionally, the IME PLE has been the object of some research studies about new teaching/learning methodologies in engineering and the involved investigators were integrated in the coordination team. Therefore, they have also contributed to the implementation effort, by helping on some activities. In future IME PLE editions an eventual reduction of the number of the coordination team members should be accompanied by a reduction of the overall workload, otherwise the staff will be even more overloaded.

5 PROPOSALS FOR WORKLOAD REDUCTION

A number of time-saving strategies have been equated for class of activities A, B, C and D referred in the previous section. The following discussion presents hypothetical measures and discusses implementation practicalities.

Strategy 1: to reduce the overall time spent in coordination meetings - activity A

Possible measures are: $\mathbf{m_1}$ - reduce the frequency of meetings; $\mathbf{m_2}$ - reduce the duration of meetings; $\mathbf{m_3}$ - reduce the number of coordination team members and $\mathbf{m_4}$ - change the coordination meetings from all teachers to more specific meetings such as: a) PSC staff meetings; b) tutors meetings; c) all staff meetings, therefore reducing the number of meetings attendees.

Measure $\mathbf{m_1}$ have been attempted in past PLE editions and the resulting frequency has not been considered of special relevance. Measure $\mathbf{m_2}$ is not considered realistic since past PLE experience shown that is not possible to go much lower than a 1-hour meeting to go through all meeting agenda items. Measure $\mathbf{m_3}$ can be considered, which would result in effective gains in man-hour requirements, but at a risk of degrading coordination team cohesion and a lower acknowledgement of student teams work and project progress. Measure $\mathbf{m_4}$ exhibit the strongest potential of improvement, since all-staff meetings would remain but in a lower occurrence, while issues raised with $\mathbf{m_3}$ would be solved, enabling to follow teams work and project progress.

Strategy 2: to reduce the time on the tutorial sessions – activity B

Possible measures are: $\mathbf{m_5}$ – reduce the weekly session from one hour to 30 minutes and $\mathbf{m_6}$ – change the frequency of the tutorials from weekly to bi-weekly.

Measure $\mathbf{m_5}$ and $\mathbf{m_6}$ do not gather consensus among the coordination team members because tutorial sessions are perceived as a fundamental activity to monitor project progress and spot internal conflicts (Alves et al., 2007). The rapidly resolution of such conflicts is considered of high importance for a good project progress.

Strategy 3: reduce the time spent by staff on students presentations – activity C

Possible measures are **m_7** - reduce the number of presentations and **m_8** - reduce the number of staff attendees.

The development of transversal competencies is one of the key aims of the PLE methodology. According to Mesquita et al. (2008) some of the main competencies searched by industry in IME professionals, that the PLE methodology helps to improve, are working in teams, leadership, project management and communication. One such competency is explicitly aimed at giving presentations to an audience. Therefore, training students and teams, by teaching them the basics on how to give presentations, and on the use of tools to assist them on such a task, and force them to go through it repetitively, is considered essential. The teams have to make three presentations during the semester. The global opinion among teachers is that they do improve this skill. Therefore, giving fewer presentations (**m_7**) would not be a good idea, since it could result in a less achieved goal on the development of such a competency. Measure **m_8** could be implemented and is not considered to affect its main goal, for instance by allowing tutors (or eventually other non PSC-related staff) to skip on such presentations.

Some teachers are also convinced that teams would do a good work during presentations even with a shorter presence of the coordination team, since students individually are very much concerned on their performance with the audience (which includes all their student colleagues).

Strategy 4: to reduce the time spent on feedback on reports – activity D

Possible measures are: **m_9** - reduce the number of reports; **m_{10}** - reduce the volume (number of pages) of reports and **m_{11}** - convert intermediate project reports into PSC assignments.

The three possible measures hold a great potential for reduction of staff project-related workload. Any combination of the three is possible. Since teams receive feedback from each PSC relating the respective report contents, plus feedback on the report structure, format, bibliography, etc., each iteration on the project team report is a step forward on a higher quality report. The difficulty is therefore to achieve a balanced solution. The reports-related workload affects both student teams and teachers. This is particularly

truth for the last weeks of the semester where most of the project deliveries are concentrated. The most promising time saving solution, which could maintain the reporting quality standards, would therefore be the possibility of transferring 1 or 2 reports to specific PSC assignments. Meanwhile other mechanisms would be required to assure the development of high quality reports. The acceptable report size has been previously agreed, but there is still space for negotiation (the maximum number of pages only refers to the effective report contents, from introduction to conclusions sections), initial pages and appendices are excluded from the number of pages limit). In the authors vision it is still possible to further reduce the number of pages requirement of 25 pages (report 1), 40 pages (report 2), 60 pages (report 3), 70 pages (report 4), especially if previous report alike assignments are required within the context of PSCs and only the findings and results are included in final (or pre-final) project reports.

6 CONCLUSION

The detailed accounting of the time spent by the coordination team in the PLE methodology is now clear and there are no doubts about the higher workload imposed by the activities involved. Some strategies and measures were presented in order to reduce this workload. The analysis and discussion around these measures show the operational practicability of some and the impracticability of others. A proposal based on a combination of measures $\mathbf{m_4}$, $\mathbf{m_8}$ and $\mathbf{m_9}$ to $\mathbf{m_{11}}$ is most likely to achieve the best relation between project results and reduction of workload. Changing coordination meetings ($\mathbf{m_4}$) from all teachers to more specific meetings - PSC staff meetings, tutors meetings, and all staff meetings -, contributes to reduce the overall time spent in coordination meetings. Reducing the number of staff attendees in the presentations ($\mathbf{m_8}$). A combination of measures $\mathbf{m_9}$, $\mathbf{m_{10}}$ and $\mathbf{m_{11}}$ contributes to the reduction of the time spent on reports' feedback. Reduction of the number of reports ($\mathbf{m_9}$); reduction of reports' size ($\mathbf{m_{10}}$). Conversion of intermediate project reports into PSC assignments ($\mathbf{m_{11}}$). Some measures were considered impractical to implement due to two main reasons: a risk of compromising the learning process; a possible reduction of team members could put teachers under greater stress.

In spite of the workload associated to PLE projects, most teachers agree that this methodology brings higher professional satisfaction: a) teachers from distinct PSC work together for a full semester; b) students build up technical competencies and non-technical skills more directed to work market requirements and this fact rises students' motivation. Engagement in PLE projects also brings an opportunity for teachers from Engineering, Science and Education to work together. Teachers involved in IME PLE consider this as good reasons to sustain this innovative learning methodology.

REFERENCES

Alves, A., Moreira, F. & Sousa, R. M. (2007) "O Papel dos Tutores na Aprendizagem Baseada em Projectos: Três Anos de Experiência na Escola de Engenharia da Universidade do Minho", in IX Congresso Galaico-Português de Psicopedagogia (Número especial da Revista Galego-Portuguesa de Psicologia e Educação) (M. Peralbo, A. Barca, A. Porto, B. D. Silva & L. S. Almeida), Corunha-Espanha, Universidade da Corunha, 1759-1770.

Felder, R. M., Stice, J. E. and Rugarcia, A. (2000) "The future of Engineering Education VI. Making Reform Happen" Chemical Engineering Education 34(3): 208–215 available: <http://www2.ncsu.edu/unity/lockers/users/f/felder/public/>.

Lima, R. M., Carvalho, D., Flores, M. A. and Van Hattum-Janssen, N. (2007) "A case study on project led education in engineering: students' and teachers' perceptions." European Journal of Engineering Education, 32(3): 337 - 347.

Mesquita, D. et al. (2008) "Engenharia e gestão industrial em portugal: Uma visão da procura profissional" (in portuguese). In 5º Congresso Luso-Moçambicano de Engenharia (CLME'2008), Maputo - Moçambique.

Oakley, B., Felder, R. M., Brent, R. and Elhajj, I. (2004) "Turning Student Groups into Effective Teams", Journal of Student Centered Learning, 2, (1): 9-34.

Powell, P. C. (2004) "Assessment of team-based projects in project-led education." European Journal of Engineering Education 29(2): 221-230.

Powell, P. C. and Weenk, W. (2003) "Project-Led Engineering Education", Lemma.

Rugarcia, A., Felder, R. M., Woods, D. R. and Stice, J. E. (2000) "The future of Engineering Education I. A vision for a new century" Chemical Engineering Education 34(1): 16–25. available: <http://www2.ncsu.edu/unity/lockers/users/f/felder/public/>.

Simão, A. M. V. and Flores, M. A. (2007) "Oportunidades e desafios no Ensino Superior: Resultados de alguns estudos realizados em Portugal Resultados de alguns estudos realizados em Portugal" V Jornadas de Redes de Investigación en Docencia Universitaria, Universidade de Alicante, Alicante, Espanha, 4 e 5 de Junho de 2007

Stice, J. E., Felder, R. M., Woods, D. R. and Rugarcia, A. (2000) "The future of Engineering Education IV. Learning how to teach" Chemical Engineering Education 34(2): 118–127 available: <http://www2.ncsu.edu/unity/lockers/users/f/felder/public/>