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An integrated approach to develop professional and technical skills for informatics engineering students

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Many of the current approaches used in teaching and learning in engineering education are not the most appropriate to prepare students for the challenges they will face in their professional careers. The active involvement of students in their learning process facilitates the development of the technical and professional competencies they need as professionals. This article describes the organisation and impact of a mini-conference and project work – the creation of a software product and its introduction in the market – aimed at the development of professional competencies in general and writing skills in particular. The course was evaluated by assessing the students' perception of the development of a number of professional competencies through a questionnaire completed by 125 students from two consecutive year groups. The results indicate that the project work and the mini-conference had a positive impact on students' perceptions of the development of professional competencies.

Keywords: active learning; professional competencies

1. Active learning in engineering education

Developments in the engineering professions call for a change of the role of engineers to fulfil tasks such as negotiating and prioritising requirements, architecting systems, preparing contracts, managing projects, controlling tasks, verifying solutions against their specifications, managing teamwork, coaching and training or writing about a project (Becker 2006, Korhonen-Yrjänheikki *et al.* 2007, Lamancusa *et al.* 2008).

The aim of engineering education is to prepare students for these changing roles, implying that some of the current approaches used to educate future engineers need to be reformatted or as the first UNESCO report on engineering states:

> 'University courses can be made more interesting through the transformation of curricula and pedagogy using such information and experience in more activity-, project- and problem-based learning, just-in-time approaches and hands-on application, and less formulaic approaches that turn students off. (…) Science and engineering have changed the world, but are professionally conservative and slow to change. We need innovative examples of schools, colleges and universities around the world that have pioneered activity in such areas as problem-based learning.' (UNESCO 2010, p. 32)

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Industry criticism about lack of communication and project management skills of engineering graduates suggests that new approaches are required, as also indicated in accreditation guidelines like those of ABET (2009) and EUR-ACE (2008). Professional competencies are nowadays critical to succeed in any profession (Beard *et al.* 2007, Brown *et al.* 2009). The development of these competencies is frequently relegated to courses outside the technical disciplines or to extracurricular courses. As a result, students have limited opportunities to develop professional competencies in an engineering context. Although the concept of professional competencies is subject to various interpretations, team skills, problem-solving skills, entrepreneurship and oral and written communication are rather undisputed in engineering education (Downing 2001, Felder and Brent 2003, Markes 2006, Siller *et al.* 2009). When looking for meaningful engineering contexts to develop professional competencies, a range of active learning methods is suggested by different authors in the engineering education field (Pulko and Parikh 2003, Vos and de Graaff 2004, Heller *et al.* 2010). Problem- and project-based learning are recognised as promoting deep approaches to learning instead of surface approaches (Biggs 1999) that improve active learning (de Graaff and Cowdroy 1997) and that develop critical thinking of learners (Savin-Baden 2003). In project-based approaches to learning, students experience a learning environment that is directly related to their future professional practice, integrating the development of technical and professional competencies. As students in project-based learning work on real solutions for existing engineering problems, often based on the requests of real companies, the project work develops competencies for entrepreneurship, as they have to consider the viability of the proposed solutions in a competitive environment.

Professional and academic success in many areas depends partially on writing skills (Cho and Schunn 2007). However, students have many writing difficulties, especially when writing in a foreign language. Incorporating writing into a course is a great challenge for teachers (Lord 2008). Many authors discuss writing skills in engineering curricula (Robinson and Blair 1995, Boyd and Hassett 2000, Davies and Cousin 2002, Yalvac *et al.* 2007). Flateby and Fehr (2008) describe a system of peer review of student writing assignments that contributes to the enhancement of writing skills for engineering students. Sivilotti and Weide (2004) argue that a mini-conference, including peer review, not only improves writing skills, but also has a positive impact on oral skills, reading and critiquing skills, citizenship skills and on the preparation for future research careers. A mini-conference within the context of a subject is a form of embedded academic writing, as defended by Wingate *et al.* (2011), who describe four methods for the inclusion of academic writing: preparatory and follow-up reading; discussion and writing in class; explicit teaching of discourse and epistemological features; formative feedback. The mini-conference allows for all of these methods of embedded instruction.

Given the need to explore the development of professional competencies in general and writing skills in particular, the case study presented in this article explores the impact of a mini-conference and interdisciplinary team project carried out by students from two consecutive year groups of an Engineering Master's Programme on the perceptions of students with regard to the development of professional competencies.

2. The case study

To achieve both technical as well as transferable learning outcomes, the 15-European Credit Transfer System (ECTS) course is organised around three pedagogical components:

(1) Attending seminars given by invited speakers.
(2) Writing of a state-of-the-art survey in a topic chosen by the student, to be presented at a mini-conference.

(3) Carrying out a software project in a large team of students.

The seminars aim to prepare students for the state-of-the-art survey and the software project. The seminars are not part of this case study, as they were rather different in the two year groups, although two of them were organised to provide students with guidelines for scientific writing and on how to write a scientific manuscript in English.

3. The state-of-the-art survey and mini-conference

Students had to write a survey describing the state-of-the-art of their dissertation topic with a maximum length of 12 pages. The surveys had to be submitted to the scientific committee of the mini-conference. The students composed a scientific committee, each student reviewing three blind surveys. Recommendations, as outlined in Tables 1 and 2, were provided to enhance the quality of the reviews.

The EasyChair (easychair.org) conference management system was used to handle both the submission and the reviewing processes. The reviewing process was organised into two distinct phases, of which the first entailed producing a summary and a detailed review of the assigned surveys, including suggestions for improvements. The second reviewing phase confirmed that all authors had effectively considered the comments in the first revision; authors submitted a letter explaining the modifications that they had done.

Presentations were made to students, teachers and three lecturers, who assessed the performance of the students. Each lecturer was given a list of topics that had to be evaluated, including clarity and dynamics of the presentation, quality of the slides and compliance with the proposed timings.

Assessment criteria included:

(i) the accomplishment of the deadlines for submission and reviewing purposes;
(ii) the accomplishment of the submission guidelines, with regard to parameters such as format and length;

Table 1. Attributes of a good reviewer

Humane	Constructive, seeking ways to improve rather than reject
Competent	Understands the content, concepts and methodology
Open minded	Considers new, unconventional ideas
Ethical	Maintains confidentiality, does not misappropriate unpublished ideas, does not block publication for personal gain
Persuasive	Explains the logic for critiques
Timely	Delivers reviews on promised date
Decisive	Makes clear recommendations to editors
Diligent	Reflects on review before submitting it

Adapted from Davison *et al.* (2005).

Table 2. The contents of a good review

A summary of the paper
A general reaction to and assessment of the paper
A list of strengths of the paper
Comments about specific weaknesses
Explanations of the logic for criticisms
Advice for improving each problem
Recommendations for future research

Adapted from Davison *et al.* (2005).

(iii) a content-based evaluation of the submitted surveys;
(iv) the quality of the presentation during the public sessions;
(v) the student performance, as discussant, taking into account the pertinence of the questions.

4. The team project

The team project was aimed at the development of technical and professional competencies. The teams were large, to increase the complexity of the team management skills. Each team was composed of around 30 students from 2009/10 and 20 from 2010/11. The decision to assign a given student to one of the projects was totally random in the first year group. In the second year group, the teachers again made a random distribution, but allowed the group leaders to exchange students among the projects. In addition to the leader, the internal organisation led to the following human resource allocation (Figure 1):

- Requirements and analysis team (REQ), to capture the requirements from the stakeholders and to transform them in pieces of the project.
- Architecture (ARCH), to conceive the software design and to orchestrate the different technologies.
- Development (DEV), to transform the design specifications into a source code.
- Documentation (DOC), to ensure that every software component is documented.
- Tests (TST), to ensure functional, stress and load testing.
- Entrepreneurship (ENT), for business plan and marketing materials.

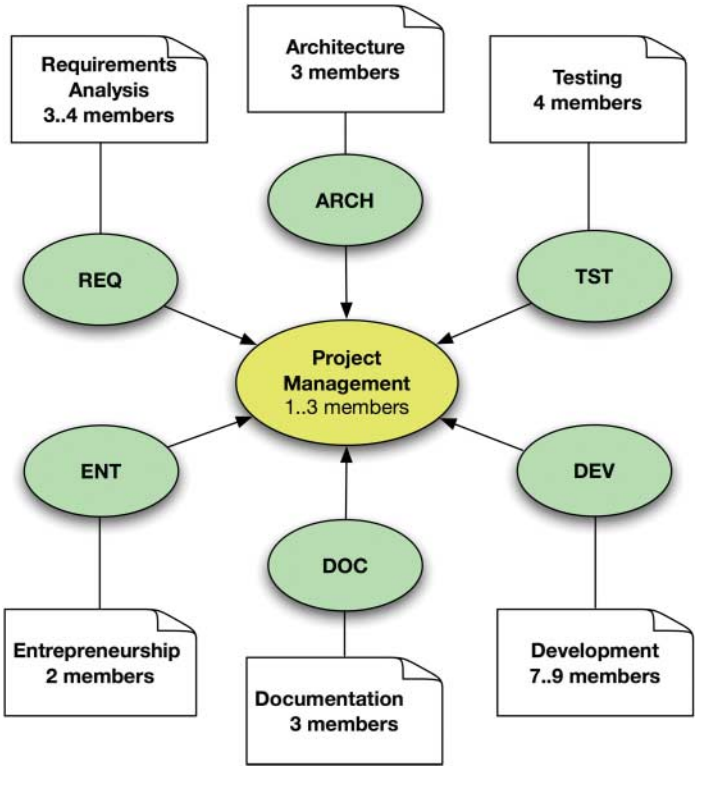

Figure 1. Internal organisation of a team, defined by the students (2009/2010 year group).

Two types of projects were developed during the course, either proposed by: (1) students; or (2) external customers. In order to stimulate entrepreneurial competencies, students had to employ project management techniques and deliver a cost-effective solution. There was also a challenge to promote this academic project as a seed for building start-up companies. The students were told that they would need to present a business plan to support the business development and to produce the related marketing and communication materials. To sustain the business plan, the students were advised that, although the customer had a specific project in mind, the ultimate goal should be to address the clients' requests as an instance of the generic product they would have to build.

The teams were evaluated according to the three criteria: product; process; entrepreneurship/marketing.

In the product criterion, the teachers used the following three sub-criteria:

Functionality. The teams had to understand what their clients expected as an outcome of the projects.

Generality. The teams had to consider generalising their clients' requirements to foster the development of a flexible product.

Evolution. The teams were also advised to consider possible development paths that could be suggested either to the client after the final product deployment or as an internal project. It was also suggested that they try to identify software components that can be reused in the future, or open-source them, thus minimising their future development costs.

In the process criterion, the following three sub-criteria were considered:

Management. The teams were evaluated regarding management activities according to several criteria. They had to identify the main stakeholders and establish adequate communication and reporting channels with them. Teams had to identify the skills of their members. They also had to break down the project into smaller tasks, identify their dependencies, establish realistic milestones, evaluate the manpower needed to complete them, allocate human resources according to the required and available skills and schedule the tasks.

Release cycle. Teams were informed that they were able to freely choose their software development and release cycle methodologies and they were evaluated according to their success on how effectively they employed them. Teams were also expected to establish a collaboration infrastructure, enabling a distributed version control of source code and documentation, supporting internal and external issue tracking and internal mailing lists.

Documentation. Teams were evaluated according to how rigorous and complete their project documentation was. This had to encompass project planning, architectural design, infrastructure and technological choices and internal and external communication with the stakeholders.

Finally, three sub-criteria were taken into account in the entrepreneurship/marketing criterion:

Business plan. Teams had to develop a business plan, either for their specific or generic product. This encompassed a strength, weakness, opportunity and threat analysis, that is, they had to 'scout' their potential markets for competitors, their offers, funding needs and develop market and financing scenarios. They also had to assess both their ability to gain market share and their vulnerabilities according to those different scenarios. Top management also challenged the teams to consider their project as a potential 'spin-off' and to prepare an application to submit to an innovation programme.

Marketing materials and effective communication. The teams were expected to develop a corporate image and product branding, including a website and promotion materials.

Presentation. The final and formal presentations were expected to have an internal scope. The teams were asked to self-analyse their achievements and difficulties to adhere to their initially

established project development plan. The students of the second year group had to participate in a peer assessment process, including five criteria on individual performance within the team. During the semester, four peer assessment sessions took place.

5. Differences between the first and the second year group

Although the overall purpose was the same, there were some differences in the two years of the course. The full set of 10 seminars organised in each year was not identical, due to the unavailability of the same speaker and to better match the content of the seminars to the needs of the students.

Another difference is that in 2010/11, one of the teams was allowed to address a business idea proposed by some of its members. In 2009/10, all business ideas were suggested by the teaching staff; in some cases, in coordination with industrial partners.

Finally, a peer-assessment process was added in 2010/11, leading to an individual correction factor of the final group grade. This assessment was used to allow the students to improve their behaviour based on the recommendations of their peers and to allow the professors to identify possible problems in the teams. The peer-assessment process reflects the principle of constructive alignment (Biggs 1999) in the sense that students who have to learn how to do effective group work define assessment criteria and assess each other at four different times with regard to the defined criteria on behaviour in the group. The teacher was not able to do this type of assessment, as he was not fully aware of the processes that take place within the groups. Rust (2002) recommends the use of peer and self-assessment and suggests that there should be sufficient feedback opportunities. During the peer-assessment process in this course, the students have four specific opportunities to give and receive feedback on this behaviour in their respective teams.

6. Method

6.1. *Population*

The participants of this study were students of a 15-ECTS course called UCE15, which is part of a two-year master's degree on Informatics Engineering at the University of Minho, Portugal. The degree takes four semesters and consists of a total of 120 ECTS. In the first year group in 2009/2010, 64 students (four female) were enrolled, whereas in the second year group, one year later, 73 (five female) students participated.

6.2. *Instrument*

The perception of the students with regard to development of professional competencies through specifically direct learning experiences was measured by assessing whether the proposed goals were achieved. Responses were anonymous to assure no bias was introduced. The questionnaire, shown in Table 3, is divided into three groups in order to evaluate: (1) the course as a whole; (2) the state-of-the-art surveys; (3) the team project. The questionnaire also includes four open questions.

The course-related questions demanded students to rate several aspects of the course, such as the workload, assessment criteria and website. Additionally, students were also asked to assess the contribution of the course work to their learning process, the motivation provided by the lecturers and the global functioning of the course.

The questions related to the state-of-the-art survey and the team project asked the students if their initial expectations with that particular component have been achieved and if their capability

Table 3. The questionnaire for the 2011/12 year group

1. Course					
From 1 (poor) to 5 (excellent), how do you rate:	1:poor		3:good		5:excellent
1.1 the contribution to your learning process	☐	☐	☐	☐	☐
1.2 the adequacy of the workload with regard to the defined ECTS	☐	☐	☐	☐	☐
1.3 the assessment methodology	☐	☐	☐	☐	☐
1.4 the motivation provided to students by the lecturers	☐	☐	☐	☐	☐
1.5 the quality of the website	☐	☐	☐	☐	☐
1.6 the **overall** functioning of the course	☐	☐	☐	☐	☐
2. State-of-the-art report					
From 1 (poor) to 5 (excellent), how do you rate the contribution of the state-of-the-art report to:	1:poor		3:good		5:excellent
2.1 the fulfilment of your initial expectations	☐	☐	☐	☐	☐
2.2 your scientific writing skills	☐	☐	☐	☐	☐
2.3 your scientific analysis/reviewing skills	☐	☐	☐	☐	☐
2.4 your presentation skills	☐	☐	☐	☐	☐
2.5 your scientific discussion skills	☐	☐	☐	☐	☐
2.6. your **current** capability to write/review scientific articles	☐	☐	☐	☐	☐
3. The team projects. General aspects					
From 1 (poor) to 5 (excellent), how do you rate the contribution of the team project to:	1:poor		3:good		5:excellent
3.1 the fulfilment of your initial expectations	☐	☐	☐	☐	☐
3.2 your ability to work in teams	☐	☐	☐	☐	☐
3.3 your communication/negotiation skills	☐	☐	☐	☐	☐
3.4 your awareness of the need for project management policies and tools	☐	☐	☐	☐	☐
3.5 your leadership skills	☐	☐	☐	☐	☐
3.6 your **current** capability to cooperate in large projects	☐	☐	☐	☐	☐
b. Peer-assessment method					
From 1 (poor) to 5 (excellent), how do you rate the impact of the peer-assessment method on:	1:poor		3:good		5:excellent
3.7 your presence in group meetings	☐	☐	☐	☐	☐
3.8 the presence of your group members in the meetings	☐	☐	☐	☐	☐
3.9 your performance in the project	☐	☐	☐	☐	☐
3.10 the performance of your group members in the project	☐	☐	☐	☐	☐
3.11 your ability to evaluate your group members	☐	☐	☐	☐	☐
3.12 your ability to give constructive feedback to your group members	☐	☐	☐	☐	☐
3.13 adapting the behaviour of the members towards the group's objectives	☐	☐	☐	☐	☐
4. Benefits, suggestions, improvements					
4.1 What impact did the course have on you?					
4.2 What aspect of the course did you find most beneficial?					
4.3 Did the course change your ideas about team work?					
4.4 What would you recommend to be improved in the future?					

ECTS = European Credit Transfer System.

to fulfil the specific component task has improved with this experience. Additionally, they had to rate whether their competencies in specific learning outcomes had improved. A Likert scale was used for all questions. The questionnaire used in the 2009/10 group did not include questions 3.7–3.11, since they are related to the peer-assessment method introduced in 2010/11.

7. Results

Respectively 58 and 67 students completed the questionnaires in 2009/10 and 2010/11. Figure 2 presents in graphical form the percentage rate for each question, its arithmetic average and error bars illustrating variance around the mean value.

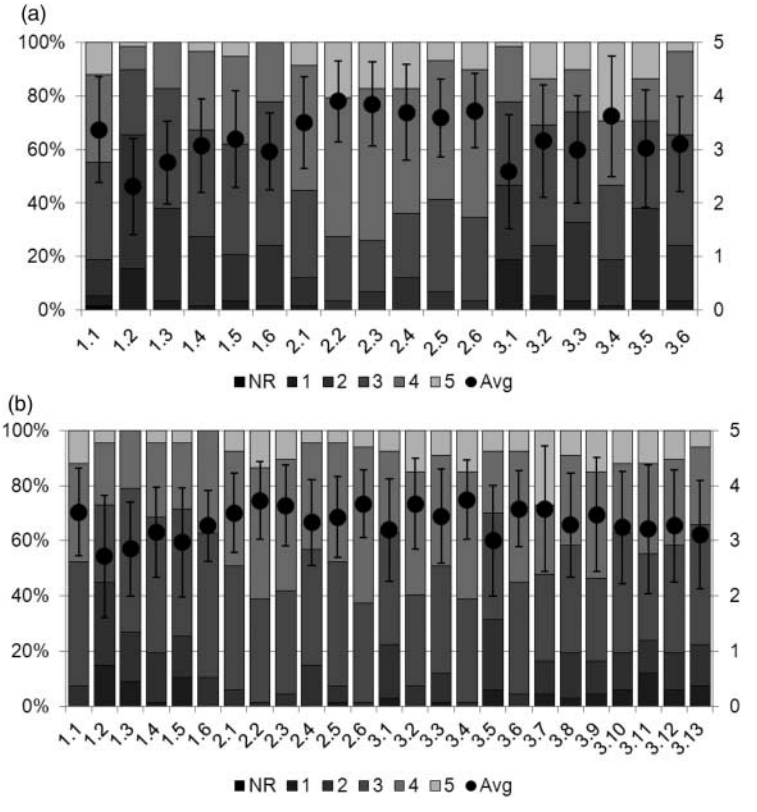

Figure 2. Rates for each question of the questionnaire filled in by the students: (a) 2009/10; (b) 2010/11. NR = no response; Avg = average.

Although students of both year groups infer that the workload is rather high compared to the number of ECTS of the course, the answers to the questionnaire show that they rate almost all topics in the range 3.0–4.0 (good – very good). Furthermore, when looking at the results of the questions on peer assessment, all item means are between 3.10 and 3.58, indicating acceptance of the assessment method and recognition of its merit in contributing to enhanced competencies.

With regard to the questionnaires, the most successful component of the course was the writing of the surveys. Students understand that writing and presenting scientific material is crucial for their careers.

An analysis of the answers to the four open questions shows rather similar patterns from the majority of the students.

The comments to the question 'What impact did the course have on you?' were mainly positive and refer to different aspects of the course. Many students argue that their writing skills have improved as the main positive consequence of the course, but also mention other positive aspects:

- 'The course has improved my skills in writing and reviewing articles as well as the competences to develop software.'
- 'I improved my writing skills of scientific articles in English and I increased my capacity to do team work.'

The seminars were mentioned by a few students and mainly received positive comments:

- 'The seminars were very good, interesting and allowed to keep [sic] the interest in the course.'

The project raised rather strong opinions, both positive and negative. Doing teamwork is one of the positive aspects of the project, as is working on management skills. The time that the project took was regarded as extremely negative:

- 'The seminars and the article had a very positive impact. The project had a very negative impact, full of disappointments and frustrations.'
- 'Improvement in doing team work, experience with a complex project and improvement of my skills in the scientific writing aspect.'
- 'Contributed for [sic] improving the skills in scientific writing and in team work. As a negative point the time spent in the course was excessive.'

For the question 'What aspect of the course did you find most beneficial?', the answers are not very different from those given to the first question. Students consider the article, the seminar and the project as beneficial. Working in a large team was one of the aspects that stood out when reflecting on the project:

- 'To know how to manage a funding proposal based on a business plan. To learn how to manage a large team. To learn the life cycle of scientific publications.'
- 'Writing the scientific article was very useful. The seminars contributed for enriching the knowledge [sic]. The project contributed to a better understanding of teamwork.'
- 'The 'adventure' was a benefit and a unique experience for my personal education.'

The answers to the third open question 'Did the course change your ideas about team work?' showed that the course, and especially the project, changed the perspectives of the students on teamwork. Students were able to see the complexity of working in a large team and the importance of leadership. Students pointed out that teamwork is hard work:

- 'It changed my perspective about the importance of leadership.'
- 'It made me see how hard is [sic] to coordinate a large group of people.'

In general, students acknowledge that they have learned a lot in the course, but they also refer to the large workload, as summarised by two of the students:

- 'Generally the course was very productive, although the project was too labour intensive.'
- 'It was a good experience, but the stress caused by the need to juggle several components at the same time was higher than the rewards in grade.'

Responding to the last open question 'What would you recommend to be improved in the future?', students give some recommendations to improve the course, focusing on the workload of the project and on a number of more practical issues, such as the weight of the final project, size of teams, offices to work in and the lack of financial resources.

8. Discussion and conclusions

The project work and the mini-conference were both aimed at the development of professional competencies for engineering students. The responses to the questionnaires as applied in both year groups show that they rate almost all topics positively, although students of both year group infer that the workload is rather high compared to the number of ECTS of the course. The responses of the students to the open questions show that they recognise both the project works as well as the writing of the article as activities that have contributed to the development of professional competencies. Embedding both the group work as well as academic writing in a meaningful context was recognised by the students as beneficial. The use of peer assessment

was also identified as contributing to the performance of individual students in a group. Students were able to acknowledge the development of professional competencies through the different activities of the course. As this course is the last one the students take before starting their Master's dissertation, an integrated approach that focuses on technical and professional competencies that they need is recommended by the authors.

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