Engineers of tomorrow and beyond
Knowledge, insight and skills needed to work across borders

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Abstract

This paper contributes to the perception of the future engineer and the competencies needed. Besides a good basic knowledge of engineering, business, technology and management our students need training in softer skills such as international cooperation, collaboration, communication, teambuilding and teamwork, language and understanding of other cultures, their behaviour, costumes, habits and expectations. The Chinese saying: "Ru xiang sui su" meaning "Enter village and follow costume" tells it all. The future engineer must be able to work in international project groups with multidisciplinary and cross-cultural participation. In the European Project Semester, EPS, described in this paper, students are exposed to a multi-cultural environment in which they study and work together on real projects provided by industry. Here new learning and teaching methods and competencies are introduced and are not just an opportunity to practice what has been previously taught. Normally students from 10-12 different universities in EU, Eastern Europe, Scandinavia and Lithuania participate. Also universities in Chile and the US are now sending their students to join. EPS contributes to international understanding and competitiveness.

Introduction

Tremendous upheavals have taken place within the last decade in Society, Industry and Education. Therefore some kind of partnership, between those who provide and those who use engineers, is important in order to establish a cradle for the 21st century engineer. It is important that education, business and industry make the profession known and attractive to young people. It is important that we motivate them to chose engineering. It is important that we secure a continuous intake of engineering students of both sexes to take over where we finish. How do we do this? How do we fulfil requirements and wishes of society, students, industry and universities? How do we make our own country a strong competitor in Europe and on the global market? How do we develop and promote peaceful and fruitful cooperation and collaboration within and across boarders? Many engineering disciplines have struggled for years trying to adjust to the ever-increasing rate of technology change. There is a general tendency to mix disciplines. However, not just the technological change and technical expertise are of importance. Other and softer skills such as collaboration and co-operation, teamwork skills, communication and languages are needed to cope with the fast changing situation[2]. The engineer is no longer just a technical specialist sitting on his own in a corner trying to solve problems alone. He/she is expected to be an integrated part of a much broader society. Besides being the technical specialist, a Danish engineer is expected to speak at least two foreign languages, to be flexible, to be able to communicate clearly and hopefully without too much ambiguity, to be able to do teamwork and to plan and manage projects. Also understanding of inter-human relations when executing projects with cross-cultural and multidisciplinary participation is expected. Certainly the paradigm has changed and will continue to do so. The tendency to allocate home computers to employees is growing fast. Also short-term contract employment is a trend. It seems to be attractive to work on distance

for different reasons among others trying to fit family life in with work life. There is a growing need to adjust and find a common denominator that suits both the employee and the employer. Also a need to develop own potentials must be taken seriously, since this is in itself, among modern employees, considered to be a quality. It is time to admit, that students and lecturers in engineering as well as in other fields of study suffer factual overload. For that reason alone we have to change the teaching form to comply with the information technology age and adjust the scheme accordingly.

Education and industry

Future professional candidates of Engineering, Business and Technology will be accustomed to working in multidisciplinary and cross-cultural teams. They will be able to apply and keen to use their broad range of transferable skills and their ability to benefit the society, the profession and themselves. A list of qualities called for in a young engineering graduate, for example that mentioned in ABET 2000[6], will beyond doubt make most of us respond by saying, that we always attempt to achieve those objectives in our courses. However, the fact that the requirements are constantly reiterated by industry indicates, that much still needs to be done. As teachers we must strive to see, that our courses are designed and structured in such a way, that the students are content and capable of functioning effectively in the industrial environment. However, industry is not entirely blameless. Their criticism is sometimes matched by a reluctance to aid education by provision of an adequate number of industrial placements and real projects. Also allocation of time and money, to be committed and engaged, is necessary. Engineering education should be a result of a partnership between the academic and the industrial worlds. It is more important than ever, to be involved and to adjust and adapt to new circumstances.

International teamwork

International teamwork done in interdisciplinary project groups on EPS is a collective enterprise involving different cultures, functions and many disciplines. Specialists collaborate on their projects as they do in typical engineering product design projects i.e. systematically and reflecting activities of the design core defined by Pugh[8].
Independent of the type of project, whether the concept is dynamic or static, the project groups are made aware of the importance of the market, the design specification, concept design, detail design, manufacture, sales and marketing. The activity is a disciplined activity that is social rather than solitary. This means that the personal design boundary is an interdisciplinary design boundary.

Personal characteristics of team members

The short intensive and project supportive courses taught on EPS break down existing barriers among disciplines and promote a common approach. However, we also believe that we advance the understanding and appreciation of the elements of the design core[8]. The process of a successful design or project is better understood. This is primarily due to the active involvement of all team members in this collective effort of specialists with different kind of expertise. We see how important a good combination of personal qualities and individual skills are. To some extent this is revealed by their individual self-perception inventory BELBIN[9] test.

Merits of teamwork

People in business and industry, interested in the skills that our graduates possess when they leave university, and people in education seem to agree, that it is important to teach our students: 1.To be trustworthy and responsible. 2. Not to be afraid to tackle problems on their own 3. To communicate without ambiguity and to listen actively (empathic listening). 4. How to find and select relevant material from what is often a bewildering pile of data and information 5. To read, speak and write English. 6. To work in teams. Students often become frustrated since they find it hard to understand how to make an original, worthwhile and personal contribution from reading all the relevant information found. However, M. Finneston provided in "Engineering our Future" H.S.M.O., London, 1980, a stimulus. Doing teamwork is more than ever a skill required to be able to function in international collaboration and co-operation[4]. It seems to be an important part of the career of an engineer of tomorrow (ref. 7). The European Project Semester (EPS), which is about international teamwork, is a balanced mix of conventional taught courses and team-based project work. After six years with this semester, we find it inconceivable to contemplate former teaching and learning methods. A few years back, before the start of EPS in 1995, a guest lecturer at the Engineering College of Elsinore made a remark that made us reconsider our situation. He was teaching a conventional class and experienced how demanding our students could be. He came from a university where they tried to teach students to find their own way and stand on their own feet, which he clamed develops more independent and creative students. His remark was: " Your students might be better analysts, but our students are more creative and dare take initiatives" and further, he said " You are spoon-feeding your students to much". This made us stop and think. On second thoughts he is right. Instead of making adjustments we kept on trying to squeeze more and more knowledge into the existing formally taught courses. We can see now that the result was frustrated and overloaded students and lecturers. After all we simply had to recognize, that students suffered factual overload and do something about it. This was one of the reasons behind EPS. Students have to be given a chance to use their acquired knowledge during their study to find new information and use it in a relevant context and discuss it with others in order to form their own personal opinion. The success of project-organised teaching on EPS is measured by the way in which the students handle situations and problems occurring during execution of their project. Students simply have to learn to take responsibility of their own situation and learn to appreciate that it is a life-long situation. Doing international teamwork is more than ever a skill needed. It will be an important part of the career of the future engineer.

Assessment of technical and soft skills in teamwork

Students participating in EPS have varying educational and cultural backgrounds. The focus is on **people** involved; on the **product** produced i.e. the group report and on the project execution **process** performed, that is the teamwork[1]. This requires a minimum of technical background and good linguistic English skills. Also good understanding of communication among people, by all means the ability to listen (empathic listening) and of project planning is necessary[3]. Students should be involved. Lecturers and supervisors are expected to be committed[4]. In figure 1 is shown an overview of elements assessed and people involved in the evaluation.

EPS exam	%	Supervisor	External examiner	Student
1. Oral presentation **PERSON**	15	X	X	
Report: 50% **PRODUCT** 1. Technical content 2. Communication Value	 35 15	 X X	 X X	
1. Teamwork **PROCESS**	35	X Point distribution and weighting factor		X Point distribution. Self and peer assessment
Total	100			

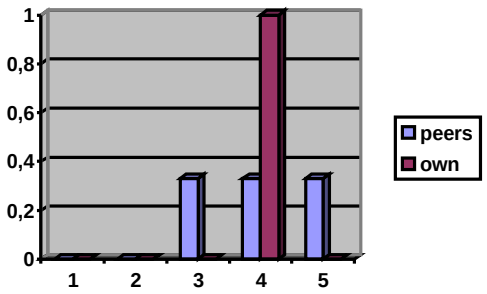
Figure 1 Assessment overview

Self and peer assessments

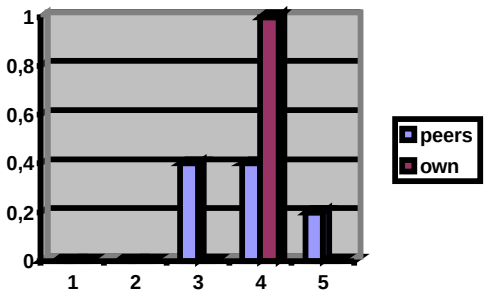
Individual contribution in teamwork is important and always a key issue when the talk is about group project work. To reflect the workload pulled by each team member, during the project execution, and to prevent free riders, team members and team supervisors are asked to distribute 100 points among the students in the project group, see figure 1. Workload means each team members technical contribution in major field of study as well as their contribution or effort, as a responsible team member, to make things work if something goes wrong. Also to care and nurture to suggest and facilitate the execution of the project process (teamwork). Questions asked and assessed in that connection are described in detail in[1]. Each team submits an interim report and discusses it with the team supervisor. In addition each team member submits a written answer to each of the following questions:

1. What is your professional contribution?
2. What is your opinion of the group performance?
3. What is your social contribution to the teamwork?
4. What is your opinion of the work done?

Self and peer assessment is done twice during the semester, at mid-term and when the final report is submitted. Feedback is given to each student. Examples of such a feedback is shown by the histograms in figure 2. Vertical scale is percentage of people involved and on the horizontal scale marks given, 1 is lowest and 5 highest score.



Professional contribution in major field .



Understanding of the teamwork process

Figure 2 Self and peer assessment results

Communication in international teams

In dealing with internationally mixed project groups all people involved learn how important communication is[3]. Everybody wants to practice his English. On a general level this seems to be fine but technical conversation is very difficult. There are several reasons for that, among others existing barriers which have to be broken down. Therefore it is recommended to ask or even urge students to have frequent meetings and interaction with each other especially in the beginning. They must get to know each other, early on, both on a professional and social basis. The ideal supervisor should dare to nurture and facilitate this process. One thing that often strikes foreign students is the fairly free relationship we seem to practice between a student and his professor here in Denmark. It is very embarrassing for foreign participants and it takes a while for them to adjust and adapt to the new circumstances. Therefore it can take a while, to develop a relaxed relationship to the supervisor. Members of a project group, consisting of a cross-cultural mix usually have to struggle to create a good social environment and good understanding of each other. Also good communication without too much ambiguity is difficult[5]. Therefore the efficiency, sort of say, cannot be as high as expected for a more homogeneous group of people having the same cultural and linguistic background. Students thoroughly enjoy the course and the opportunity to work in international teams. They all regard the experience gained from the EPS as being beneficial.

Supervisor roles

The main contribution of the academic supervisor is to help the students to understand the content of their project and to ensure they are making progress. It is also to nurture and facilitate group work and the project execution i.e. the teamwork. The supervisor must make sure that the advantage of working together in a group is sustained. He should know that the advantages of working together in teams are often lost because of faulty group processes, which degrade the cognitive and political activity of the group. He must help the team members develop shared commitments and make sure that they work collectively to achieve them. Students of today take a different attitude towards the lecturer and supervisor. It is no longer expected of him to be autocratic as such but it is required of him to be qualified to answer questions. Supervisors should be able to advise and guide the project group in its seeking for solutions. It is crucial that the supervisor shows a real interest in the group. He must pay attention to the group and lead it in the right direction. Students on the course are asked to allocate a mark from 1 (lowest) to 5 (highest) that most accurately reflect their individual opinion of each of the points mentioned below:

A good team supervisor should have the following qualifications:

1. Good communication skills in English to prevent ambiguity
2. Show a real interest in people, their behaviour and expectations
3. Show good management skills
4. Show good active listening skills
5. Not be afraid of unstructured situations
6. Understand how to nurture and facilitate teamwork
7. Have knowledge of cognitive and political problems that can occur in teamwork
8. Have knowledge of group psychology and group dynamics
9. Know how to guide and lead people
10. Know what teamwork is about
11. Have knowledge of different cultural behaviour
12. Know how to lead and hold a meeting
13. Know how to write a good technical report

14. Show an interest in personal development and life-long learning
15. Appreciate that teamwork is more than just group project work
16. Have a good technical knowledge/background in subject area

Statements

- It is not enough to tell and show students they must be INVOLVED to learn.
- There is a tendency that we spoon-feed our students too much
- We still try to squeeze more and more new knowledge into the syllabus of a formally taught course. This results in frustrated and overloaded lectures and students.
- Students must learn to take responsibility of their own situation and learn to appreciate that learning is a life-long situation.
- There should be a radical change to education and training. After seven years with international teamwork, we find it inconceivable to contemplate former learning and teaching methods.
- An appropriate mix of learning and teaching methods has proven to us, on European Project Semester, EPS, at Ingeniørhøjskolen i København, Denmark, to be good.

Conclusion

We must emphasise the development of technical as well as personal competencies and softer skills to meet the identified needs of industry, university, society and students. We must give students an opportunity to make use of their acquired knowledge. We must give them a chance to develop a deeper understanding of technical subjects and use them through work in an integrated engineering context. We must give our students international experience already during their study. We must improve the student awareness of international affairs alongside their enhanced technical, social and linguistic skills. It is important to expose students to cross-cultural communication and understanding. Students and professors must learn about cognitive and political problems in teamwork. We must all learn to be active listeners. The European Project Semester (EPS) is an appreciated and recognized semester that contributes to international understanding and competitiveness.

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Biography

ARVID ANDERSEN
Following 17 years in Swiss, American and Danish industries Arvid Andersen, BSc, MPhil/PhD, Eur Ing joined in 1978 the academic world. In 1989 he was one of the founders of Institut for Konstruktions og Energiteknik at the Engineering College of Elsinore in Denmark. He implemented Project Organized Teaching at the institute and in 1995 he started the European Project Semester (EPS), which is about interdisciplinary and international teamwork. He is director of EPS now located in the Export Engineering Department at Ingeniørhøjskolen i København, Denmark.

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MSc. In chemical engineering. Has been working 16 years in the Danish Institute of Technology with chemical unit operations, process control, energy techniques and environmental protection. Since 1985 J.H. has been associate professor of the Engineering College of Copenhagen (Ingeniørhøjskolen i København) teaching the same and some other disciplines. Since 1998 Jørgen Hansen has been cooperating with Arvid Andersen doing the EPS.