Position of the final year project in an engineering curriculum

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ABSTRACT: The final year project is a typical requirement in an engineering degree. It introduces the students to professional engineering practice by providing them with an opportunity to work on an open ended engineering problem. Typically, the students would apply knowledge from different areas or courses, which they have studied in their curriculum using methods, tools and techniques, which they learned to a real-world scenario. The project is also a major requirement for accreditation of an engineering programme. This is due to the fact that students would have to apply not only their engineering knowledge and proficiencies (hard skills), but also to demonstrate their competence in generic, professional skills (soft skills). The project is also an ideal place to assess both types of skills. This article highlights the importance of the final year project in an engineering curriculum and advocates for industry based projects to be more commonly used. It also emphasises the importance of life-long learning as a fundamental attribute of graduate engineers.

Keywords: Final year project, engineering curriculum, student's attributes

INTRODUCTION

A project is a typical requirement in the final year of any undergraduate programme in engineering. It is sometimes called a *capstone* [1] as it should require from a student an element of synthesis; to combine knowledge from a few or several courses in order to solve a particular engineering problem [2]. Normally, it should be a design project or at least should have an element of design. Such a project is also a typical requirement for accreditation of any engineering programme.

Students carrying out such final year projects are applying knowledge from different areas or courses which they have studied in their curriculum. However, through performing the project they may also acquire new knowledge in topics not covered in the curriculum or, more often, extend their knowledge in areas they have already studied [3].

The final year project gives the student an opportunity to use and implement methods, tools and techniques, which they learned to a real-world scenario that an engineer may be expected to face upon graduation. The project has a unique position in engineering curriculum and some argue that the quality of student output in that course can be used as an indicator of the quality of the programme as a whole [2].

FINAL YEAR PROJECT IN ENGINEERING CURRICULA

It is a common rule in engineering curricula to introduce a final year project. The future engineer is to face an engineering problem and solve it, with the help of his supervisor, using the concepts and knowledge assimilated during his or her engineering education. The project is the pinnacle of the engineering degree programme where the student makes a synthesis of the information received to use it to solve an engineering problem in a particular discipline or across disciplines. It is also a vehicle for many skills required for engineering graduates [4].

The final year project in engineering curricula is normally and ideally a design project [5]. It is the culmination of all the subjects learned in various courses in particular disciplines within the engineering curriculum. It is intended to be a major educational experience and a rewarding effort on the part of both students and the member of staff, i.e. the supervisor.

The goals of the project are:

- To give the students an experience of carrying out an individual project and sense of accomplishment associated with such an undertaking.
- To encourage the students to make a meaningful intellectual commitment to an engineering problem.
- To help in the development of one of the most important attributes of an engineer - self-discipline.
- To emphasise the use of fundamental concepts, and use of texts and references rather than rely on staff members for all of the answers.
- To emphasise the presentation of technical material by informal summary reports, drawings, formal reports and presentations.
- To help the students to critically evaluate their own work.

In some cases, the project may be related to an action research project for a period of one academic year to improve the effectiveness of the final undergraduate project in engineering [6]. In that way the quality of the final year project is improved by fostering a deep approach, which can also be promoted by putting more emphasis on the preliminary problem selection for the projects and peer interaction stimulation.

The final year project is always a major requirement for any accrediting body [7]. All the Washington Accord [14] signatories have defined the following items as consisting of the essential features of an acceptable design project:

- Development of student creativity.
- Use of open-ended problems.
- Formation of design.
- Problem statement and specification.
- Synthesis of alternative solutions.
- Feasibility.
- Detailed system description.
- Consideration of constraints (e.g. economic, safety, reliability, etc).
- Utilisation of engineering and scientific principles.

PROJECT REQUIREMENTS

The final year project is necessarily different from other typical engineering courses within the engineering curriculum as it provides for the students to work on an open ended problem, which may have a few or several solutions or design options [1]. It is also different to other courses in the sense that it should provide a real independent learning opportunity. The project should also address the gap between academic study and application of that knowledge in real life situations in engineering practice [8].

In order to satisfy the above requirements, the ideal design project must satisfy the following criteria:

- The project must be integrative; the student must integrate the material from several of the disciplines of particular areas of engineering.
- Each project must have meaningful analysis; analysis will usually be required in completing the synthesis.
- The project must have meaningful synthesis; various alternatives must be considered, evaluated and the most suitable alternative selected.
- The presentation (written report, drawing and oral presentation) must be of professional quality.

There are also additional requirements depending on the specific engineering discipline. For instance, in mechanical engineering one of the specific requirements will be manufacturability, as this item has to be a concern to all mechanical engineers. Hence, manufacturability is to be considered throughout the project and a manufacturability summary should be included as part of the final project summary in the report.

The further requirements common to all engineering discipline would include the following:

- Economic analysis - the design of any item must include some cost analysis whether it is a single item or a mass produced item.
- Safety analysis - there are few if any items, which will not have safety implications. Safety is not some obscure meaningless regulation to be ignored whenever possible, but is a serious concern that every engineer must address.
- Final evaluation - the final evaluation of proposed design should be a critical self-evaluation of team effort. This evaluation should consider such items as how good is the design, what would be needed to complete the design, what changes could be suggested for improving the design.
- Environmental impact - environmental issues have become crucial and environmental consequences (positive or negative) of any engineering solution should be carefully considered and addressed.
- Social impact - can be part of the environmental impact, but can also be considered as a separate item looking at the consequences of the engineering solution on the community and well-being of the individuals and families.

The ideal design project should be done in a certain sequence [9]. Three major steps can be identified:

- The first step would cover design needs, problem recognition and definition, proposal writing, searching and optimisation techniques leading to an algorithmic approach to design, cost estimation and economic evaluations.
- The second step provides a complete design experience under professional guidance. This step covers the actual design of a project.
- The third step includes completion of the design project, design liability, design presentations, design report, design evaluations and manuals.

The project is important to students not only because of the educational benefits, but also because it can bring some other benefits, such as getting a better job or special awards [10]. Some of the items, which should be considered by students are summarised below:

- A student who does an outstanding project gains self-confidence that carries over into his/her other work and which is also observed by the interviewers for a job.
- Many students prepare brief summary documents on their projects and take these briefs with them to interviews. The impact of this effort can be significant.
- The students are encouraged to enter a local/regional/national student paper contest where they compete with students. High quality oral presentations usually are made on the best designs.
- In some countries, there are national prizes for student design projects. Each year many students have projects which are eligible for submission to these contests. Prizes are significant and the resume impact is more important.

Ideally, the project should be done in teams to provide students with the team-working skills. It would also improve communication with the supervisor and free exchange of ideas with peers. Team projects allow on building experiences how to resolve team conflicts and how to work with people who are not necessarily friends.

Teaching, or supervising, a final year project is, however, not without challenges for academic staff and may endeavour with many considerations. There are several problems related to initiating and supervising of the projects and, especially, the following items require careful attention by staff:

- Careful selection and definition of the project scope;
- Proper time and resource planning;
- Effective management of uncertainty related to the open-ended aspect of the project;
- Effective strategy for conflict resolution.

Although, it is mostly not a formal requirement, it is only highly recommended that the final year projects are coming from industry. Although there may be some difficulties in managing such projects they have the advantage of bringing an additional flavour to the course as in that way the students are indeed working on real life engineering problems and have direct contact with people from industry.

ATTRIBUTES ADDRESSED BY THE FINAL YEAR PROJECT

The final year project can act as an instrument to introduce students to many skills required for engineering graduates, especially, professional skills. This has become important since the revised evaluation criteria for accreditation of engineering programmes emphasise the development of professional skills [11].

Professional skills, also referred to as soft skills, are not particularly pertinent to the technical content of study, but important in the professional practice. Traditionally, the emphasis in university programmes has been on the development of discipline specific knowledge and skills (disciplinary or vocational skills). However, increasing importance has recently been placed on the development of generic skills [11-13].

That formal introduction of professional skills to the graduation profile of engineering students has highlighted the importance of non-technical skills in engineering programmes. All accreditation agencies who are signatories of the Washington Accord demand for undergraduate curricula to be finely balance disciplinary knowledge and the more universal generic skills [14]. There are several requirements (sometimes called *criteria*), which programmes seeking accreditation should demonstrate to have achieved. One of the fundamental requirements for accreditation is that the students should attain a list of prescribed outcomes. All accrediting bodies list those outcomes and they are very similar, but differ slightly in formulation or their number.

None of the accrediting agencies specifies the extent to which each learning outcome should be mastered by a graduate and is left for an institution. The decision of what the specific blend of skills carried by a graduate should be is not straightforward [15-17]. However, some decision at the stage of curriculum design or change has to be made in order for the graduate to gain certain skills and to be presented with some attributes.

The Accreditation Board for Engineering and Technology (ABET) in its third criterion for accrediting engineering programmes suggests five technical and six non-technical student outcomes [7].

Not surprisingly, the hard skills include:

- an ability to apply knowledge of mathematics, science, and engineering (3.a);
- an ability to design and conduct experiments, as well as to analyse and interpret data (3.b);
- an ability to design a system, component, or process to meet desired needs *within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability* (3.c);
- an ability to identify, formulate, and solve engineering problems (3.e); and
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (3.k).

It is this second set of six outcomes, the professional skills that have formed the most controversy, but also have created the ideal venue to be addressed by the final year project course:

- an ability to function on multi-disciplinary teams (3.d);
- an understanding of professional and ethical responsibility (3.f);
- an ability to communicate effectively (3.g);
- the broad education necessary to understand the impact of engineering solutions in a global, *economic, environmental,* and societal context (3.h);
- a recognition of the need for, and an ability to engage in lifelong learning (3.i); and
- a knowledge of contemporary issues (3.j).

The final year project is without any doubt a proper vehicle to address both hard skills and soft skills, which actually complement each other. Identifying and solving an open engineering problem (3.e) which may involve design of both experiment and/or a system applying knowledge of engineering (based on mathematics and science) (3.a) and using all necessary engineering techniques and tools (3.k) is, indeed, the main expectation. However, economic, environmental, social, political, ethical, health and safety, manufacturing, and sustainability (3.c) constrains are vital and have to be addressed. The knowledge in those areas goes beyond the hard engineering attributes and covers elements of soft outcomes. The solution achieved in the project has to be presented clearly and concisely. Also, students have to apply a pragmatic approach checking whether the best solutions is actually a simple one and may not always involve complex analysis based on sophisticated methods.

The goals of the final year project is to broaden the students' perspective on engineering, to apply creativity and critical thinking, understand the ethical (3.f) and historical context, and also to deal with economic and environmental issues (3.h), as well as possibly customer service. It is the unique sense of project-based learning, which also provides students with such soft skills as communication (3.g), teamwork (3.d), sustainability and social commitment (3.h), information search (3.i), management (3.h) and autonomous learning (3.i).

The important aspect of the final year project is teamwork and activities related to peer collaboration. It is, indeed, unfortunate that in some cases engineering institutions insist on individual projects instead of persisting with group work. It is understandable that a group approach may create some extra difficulty and issues mainly related to its assessment and the contribution of each team member. However, such issues may be overcome with some motivation and readiness to apply slightly more complex forms of assessment of team-based evaluation [18].

The benefits of students' experience working in a team overcome greatly the supervisors' difficulty in assessment. Collaborating with others, being a team leader or even being a team member is an extremely important lesson to learn before actually joining the engineering work force where nothing is done in isolation.

The final year project also addresses the ability to undertake life-long learning, which should be considered as the most important of professional (soft) skills for graduate engineers. The life-long learning concept is no longer some additional training after graduation, but it is inclusive of all activities covering the entire active life of a graduate. It is quite likely that engineering programmes that intend to remain up-to-date with industrial practice by just continually providing course up-dates or new courses to reflect new developments in technology will be unsuccessful.

This is mainly because the world changes rapidly and, especially technology develops quicker than the time taken by the educational institution to identify and respond to new industrial needs. It is quite likely that by the time the students are trained and graduate, the technology used has already changed. Graduate engineers equipped with skills and committed to life-long learning would be able to face new challenges both in terms of the knowledge and also possible job profile change. It should provide engineers with the ability to rapidly update their knowledge and also to acquire those elements, which they missed in the course of their formal education [19].

Especially advantageous are final year projects based on industry problems [20][21]. These may include industry sponsored projects or projects attempting to solve industry problems spotted either by students themselves or by staff members. Despite the fact that such projects may have challenges related to technical and administrative issues,

they indeed provide an authentic experience of industry problems. *Real* problems enhance student motivation also by providing them with an opportunity for future career placement. The contact with industry also provides a chance of a realistic environment not only in terms of the problem but also in terms of economic and management aspects. Such projects may present an opportunity for financial support for practical realisation of the outcomes.

CONCLUSIONS

The final year project creates challenges to the academic staff of engineering institutions. Continuously and consistently finding projects that are at the appropriate level, with the possibility for a fair and consistent method evaluation, especially for group projects, may cause a real difficulty for supervisors. However, there is no question that the benefits outweigh the possible problems related to projects preparation and management. That applies to both industry-based and not related to industry projects.

Essentially, the goal of the final year project is to introduce students to professional engineering practice. In project work students are engaged in the analysis, synthesis and application of the courses covered in their studies. It provides links between different areas of knowledge both covered in the curriculum and newly learnt by students. Dealing with issues of liability, sustainability and project management should provide students with skills and knowledge of a competent engineer. It exposes students to a range of hard and soft skills and allows for holistic evaluation of students' ability and aptitude.

The final year project creates a great opportunity to students to value and appreciate life-long learning. It clearly shows that the engineering curriculum cannot provide graduates with all knowledge necessary in engineering practice, and that engineers should have the ability to acquire those elements of knowledge that were not included in the course of their formal education and keep updating their knowledge through concern for acquiring other relevant skills.

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