

pble
project based learning
in engineering

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Project Based Learning in Engineering (PBLE)

PBLE is a project funded by FDTL (Fund for the Development of Teaching and Learning) phase 3. The project is nearing the mid point of a three year programme and aims to collate and disseminate good practice in the use of project based learning in engineering education in order to assist those setting up projects. The project intends to give the widest possible coverage to all engineering disciplines and teaching levels. The project team welcomes further input and assistance from all interested parties. We currently are seeking material on methods, techniques and procedures, as well as case studies and examples to continue to inform and broaden the inputs to the project.

The following gives an outline of the main development areas of the project, to which we would gladly accept input:

Publication

A manual will be produced containing the information gathered by the project team. Contributions to the document may include: *Case studies, extracts from additional material, such as: conference proceedings, literature reviews, and relevant material from other disciplines.*

Dissemination

Awareness and distribution of the gathered material is an essential part of the project. Local assistance is sought for events including: *Workshops, staff development, personal contacts, material distribution.*

Evaluation

The utility of the material distributed requires evaluation. The project is willing to fund, or would be grateful for access to: *Staff and student feedback documents, and formal evaluation procedures for projects using our frameworks.*

Volunteers

Funding is available to cover the cost of preparing material and running workshops.

Web Based Discussions

To allow effective discussion and propagate views and resources we have created the following web-based discussion groups:

pble_announce, a low-traffic announcements service from the project – giving details of workshops, publications, conferences and so on:

http://groups.yahoo.com/group/pble_announce/

pble_discuss, a forum to discuss PBL related issues with members from many educational institutions:

http://groups.yahoo.com/group/pble_discuss/

pble_review, a forum to review PBL related resources, including journal articles, web sites and events:

http://groups.yahoo.com/group/pble_review/

Workshop Materials

All workshop materials can be found on the website:

<http://www.pble.ac.uk/group-workshop-2001-11-21/>

This document is an extract from a draft prepared by the Project Based Learning in Engineering (PBLE) project. The research for the project is still ongoing and contributions are actively sought on all aspects of the topic including the Group Projects topic covered at this event. Project Based Learning in Engineering. The PBLE project is a phase 3 project funded by FDTL (Fund for the Development of Teaching and Learning) nearing the mid point of a three year programme. The project looks to the collation and dissemination of best practice in the use of project based learning in engineering education and to make the results available for those setting up projects. At present the work is centered on the original consortium institutions; The University of Nottingham, Loughborough, Nottingham Trent University and De Montfort University but it is now intended to widen the input. Although the experience of others is already being collected through a series of visits to institutions that have contacted the project the project team would welcome further input and assistance. The project is aimed at the widest possible coverage of engineering disciplines and teaching levels and material on methods, techniques and procedures as well as case studies and examples are sought to complete the research. The following gives an outline of the main development areas of the project at present

Publication

A teaching manual will be produced containing the information gathered by the project team.

Contributions to the document would be welcome and may include:

- Case studies
- Conference proceedings
- Literature reviews
- Awareness of material from other disciplines.

Dissemination

Awareness and distribution of the gathered material is an essential part of the project.

Local assistance is sought for events including:

- Workshops
- Staff development
- Personal contacts
- Material distribution
- Web discussion groups.

Evaluation

The worth of the material distributed requires evaluation.

User response is required through:

- Staff and student feedback documents.
- Formal assessment procedures.

Funding is available to cover the cost of preparing material and running workshops

Planning

Staff Planning

The teaching schedule in Project Based Learning has some significant differences from lecture based programmes where a rigid timetable of events (lectures, tutorials etc.) is set up in advance.

If the full potential of project based learning is to be realised, a new relationship for the teacher needs to be established. The teacher should no longer be seen as the primary source of information, but must become an advisor, learning with the group. In addition, with multi-disciplinary projects, individual lecturers may not have the necessary expertise in some areas of the topic.

A major teaching input will be required before the project starts. Essential learning material will be required from the outset if groups are to plan their own programme and devolve tasks within the group. The involvement of specialists from other disciplines or industry makes it crucial to set up availability and access procedures. The demand for specific input should come from the group, and, after an initial briefing period, will require expertise to be made available when needed. The detailed programme should be group generated within pre-set targets.

Clearly defined objectives should be set for each stage of the work. Feedback following the stage submissions will record progress but the use of group presentations will clearly demonstrate relative performance across the group. The setting of targets will have a major effect on the overall success of a project. Sufficient freedom should be given to encourage speculative avenues to be explored but a framework of deadlines is required to keep progress on track. The impetus of an interim submission should be recognised at the planning stage together with the equally noticeable loss of momentum that follows

Project Design Requirements

Having defined the general scope of the project, the detailed design requirements for equipment to be designed and/or manufactured as part of the project should be specified. These requirements can be broken down into a number of checklists :-

Engineering: Spatial envelope and geometric constraints

Linking to adjacent parts

Function – mechanical

load cases, movement, mechanisms

Function – electrical

power/drive systems, actuators, sensors/measurement,

control systems

Materials usage

Bought-in components

Manufacturing methods

Durability e.g. fatigue/creep/environment

Standards relevant *BSI, ENO, DIN, ISO*

Non-engineering: Environmental impact

Health and safety

Other legal requirements

Recyclability

Business/management aspects

budget costing, market research etc.

Aesthetics and fashion

The various requirements as specified under the above headings can be subdivided between the disciplines for the project or alternatively this can be a project task allotted to the student group.

Budget Costs

It is important at the outset of a project to estimate as accurately as possible the likely costs and to set a budget within which the project group should operate. This is particularly important for M-D projects as costs can accumulate in different departments.

The general form shown below can provide a simple method of calculating the budget costs for individual items of equipment or activities within the project. By compiling such forms in a spreadsheet for all components/activities comprising the project, total budget costs can be calculated and subdivided between the different departments involved.

Sources of Funding

Having completed the budget statement for the project it should be clear how the individual components/activities subdivide between departments involved. However, the sources of funding to meet these costs may be divided differently and not along simple component/activity lines. Industrial and/or external funding or in-kind support, e.g. supply of equipment, is particularly beneficial in reducing overall costs. Because of the long timescales often required to secure external funds, it is important to start early in the search.

The following sources might be considered: -

Industrial cash and in-kind funds

Research project funds

Earmarked departmental and/or University funds for specific initiatives

Participating departments general teaching funds

Control of Expenditure

The most important aspect under this heading for M-D projects is to ensure that, at the outset of the project, resources and funds are available and that there is an agreed written statement of who has responsibility for each element of the budget statement. Thus, it is clear where the funds are coming from and who is monitoring expenditure (see next section).

Control of expenditure is particularly important. It is likely that there may be more than one supervisor for the project and work may be carried out in more than one department, making monitoring of expenditure crucial.

Students should be made fully aware of budget details and supervisors should stress the importance of maintaining expenditure within budget limits. It is important that students should obtain accurate estimates or quotations for any proposed expenditure and obtain their supervisor's approval before proceeding. Students should also be instructed to maintain full records of all items of expenditure and to report these on a weekly basis. Record keeping is good practice for students and enhances their project management skills. Regular budget/expenditure reviews should also take place involving both supervisors and students.

Actual costs can be recorded against budget costs on the budget costs form given above using spreadsheet software. Co-supervisors on an M-D project should also meet regularly to review budgets and expenditure

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Industrial Projects

Arguably there is no better environment to assess the ability of a student of engineering than within the industry itself. No doubt this was at the heart of some of the recommendations made by the Dearing Report into Higher Education¹, subsequently endorsed by the Government of the day, regarding the undergraduate experience of the world of work. This clearly states that all institutions should aim to increase the level of student learning centred on the industry it is aimed at. This is fundamental to engineering as it is in any other

career. One of the key learning activities which may be implemented or extended to meet the above recommendation, is through industrial-based projects. Furthermore, a second recommendation was made

This was probably directed at the encouragement of so-called ‘year out’ industrial placements as part of a thick-sandwich degree programme. However, the same benefits to the student learning experience arise from participation in industrial-based projects based at the institution which offer the opportunity to work with professional engineers on-site. As an engineering teaching institution develops its portfolio of project-based learning opportunities it is likely that those who demonstrate successful implementation of industrial-based projects also enjoy a thriving programme of year-out industrial placements.

This framework aims to provide ‘best practice’ in the planning and implementation of industrial-based projects aimed primarily at Engineering programmes. Particular issues that are addressed specifically to industrial-based projects rather than project-based learning in general are raised to highlight potential benefits and also the possible pitfalls. It may also be used by industrial partners themselves to develop project-based learning as an aid to raising their profile within a particular institution for the recruitment of engineers. The advantages to both institutions and universities are also explored.

However, some issues relating to the administration of projects are unique to industrial-based projects. The difficulties in obtaining company involvement on a large scale practically rule out individual projects each partnered by a different company. However, a single company may be involved in an individual project with the same objective for each student that operates on a competitive basis with the opportunity for the company to offer prizes at the end. This is equally applicable to group project work.

An alternative form of group project work is for groups to be assigned a different task and be partnered by different companies. This enables a blend of companies to be involved and the learning experience is enhanced with students forming contact with a principal company but also having some exposure with other companies.

Team Selection

There are basically three methods of team selection i.e. student self-selection, tutor selection and a combination of both (seeding).

Self Selection

Free choice groups set an appropriate base to encourage student participation. Teams which are allowed to self-select will do so through three principal drivers: established friendships, ability levels and geographical proximity. This often work well but there are, however, some significant drawbacks. Self-selected groups will create wide ability variations as the better students join forces. In practice, this may be less of a problem than might be expected, since good teamwork can compensate for lack of individual ability and a group may perform better than the sum of its parts. Also, self-selection will naturally take account of social factors which might otherwise be missed. Groups of students may share living accommodation or workplaces, making it convenient for them to work together. Scottish Universities are most aware of potential problems with a significant proportion of students living at home. For students following a range of options, timetable conflicts can make collaboration a major difficulty. The main danger is the isolation of individuals perceived to be difficult, less able or recent arrivals. There will always be some students who are unattached by the above drivers and will wander freely and attach themselves to pairs or small groups of friends and henceforth will always be outsiders.

Tutor Selection

Where the tutor selects, the choice may be random or with method. Multi-disciplinary teams may be built by monitoring the participants choice of optional modules for example, or by selecting mixed abilities through previous examination results. Potentially, the tutor could choose groups of more able or less able students from past examination results, although this is not recommended and no examples of this are known. With tutor selection there will always be complaints from students not allowed to work together, resulting in rumbling disquiet and reduced enthusiasm. On the other hand, it can be argued that the world of work throws teams together in this fashion and students must become accomplished at getting along with others. In one example, the merits of self-select and tutor choice are combined as far as possible. Students are allowed to form teams of two or four which are then combined by the tutor to make up a final group of six.

Seeding

With this method, staff may decide team leaders or “seeds” and team size. The seeds are then allowed to arrange their own groups, either by selection or by invitation. Normally the seeds will be selected according to a known ability in the intended field of study. The selection of leaders by past academic record is relatively straightforward but the judgment of leadership qualities may be more difficult. The possibility of conflict may arise, where individuals are dissatis-

fied with their group and react against the leader. However, it guarantees a minimum level of ability in all teams and avoids the totally weak teams which may arise from pure self-selection. It also enforces an element of team mixing, to foster valuable transferable skills, while retaining an element of self-selection to promote harmony. This method also ensures that the tutor can arrange the correct number of teams, of the correct size, in a short time.

Where groups are made up from different years of the course, or in multi-disciplinary projects, it may be difficult to achieve an even distribution of skills or experience. When severe imbalance occurs, the formation of “consultancies” should be considered. The members of the predominant element can gain essential input from individuals or sub-sections, serving more than one team.

Team Size

There are mixed opinions on the best size for teams. Teams from three to six have been tried with varying success in many schools. The total output of a project team cannot be directly related to team size. i.e. a team with four members may perform equally as well as a team with five in a similar environment. The findings of the survey of academics and students in the humanities by Allen and Lloyd-Jones (ref x) suggest that teams of 3 or 4 students work best. Experience in engineering shows little difference. If the team is much larger, there is more likelihood of logistical or free-rider problems.

Meetings

Regular meetings to facilitate good communication are a key factor for the successful outcome of any project. They are particularly important for multi-disciplinary (M-D) projects where communication problems can arise in a team of students from varying disciplines. All team members should be encouraged to take part in discussions and the decision making process for all aspects of the project. Students working in isolation in areas of subject specialism should be discouraged as it is often the interface areas between disciplines which can dictate the rate of progress and the achievement of deliverables for the project as a whole. Involvement in the overall decisions will draw team members together at these interfaces.

The following meetings should be arranged on a regular basis: -

Supervision Meetings

Weekly or fortnightly intervals recommended. Can usefully follow a team meeting

These meetings should involve all team members and a supervisor. Where there are two supervisors, e.g. different disciplines, a principal supervisor should be named and should attend all meetings. The second supervisor can attend on a less frequent basis e.g. monthly. The purpose of these meetings is primarily to report progress to the supervisor and to obtain comment and advice. Students should be prepared to have the project timing plan, including interim milestones, and project expenditure scrutinised.

Team Meetings

Weekly intervals recommended

The primary focus of these meetings should be monitoring and reviewing of progress on project tasks and future planning and allocation of tasks to individual team members or subgroups within the team. Project expenditure should also be reviewed against budget. These meetings are also a good forum for discussing and troubleshooting specific problem areas, such as where different disciplines interface in related tasks. A

team manager should be appointed by the team to organize team meetings and monitor overall and individual progress and financial details.

Technical Meetings

These should be arranged as necessary by a subgroup of individuals working on a specific task. They should be focused meetings looking at detailed technical matters. For M-D projects, tasks are likely to be subject specific although there may be some activities which require a multi-disciplinary subgroup.

Keeping Records

In addition to all individual team members maintaining their own log book, the team manager should maintain a project log book in which the project plan and budget should be recorded and the minutes of both 'team' and 'supervision' meetings should be maintained. The minutes should record, for each meeting: (a) progress achieved since the last meeting measured against the project tasks/milestones; (b) tasks allocated and to whom for the next period and (c) expenditure/budget review outcomes.

Communication Skills

Good communication skills are a key element in the success of any project and supervisors should emphasise this clearly to all students at the outset of a project. Communication within the project (intra-project), with external parties (extra-project), reporting progress and the ability to report and disseminate the project outcomes are all important aspects of communication. The supervisor should provide support in the form of advice and the necessary resources to facilitate good communication. The supervisor should also be prepared to 'step-in' where it is found that communication problems are jeopardising the successful outcome of the project.

Intra Project

Good intra-project communication is particularly important for group projects. The supervisor's support in this area should start at the first group-supervisor meeting where the importance of communication should be discussed. The group should be encouraged to set up a schedule of project meetings, both with and without the supervisor, at appropriate frequencies, to ensure the involvement of all group members in the key decision making and to enable monitoring of progress to take place (see next section on project management). The supervisor's support at the early stages of the project is particularly important in ensuring good practice in communication and in establishing an environment conducive to brainstorming, problem solving and decision making. Regular supervisor/student meetings should be arranged throughout the period of the project, typically weekly. This is particularly important for individual projects where, in many cases, the supervisor will be the main sounding board for progression of the project. The frequency of such meetings is likely to be higher at the commencement of the project. The supervisor should also be prepared to assist students at times other than during scheduled meetings and, in particular, when specific difficulties arise. Although students should be encouraged to tackle problems on their own, they should not be afraid to ask for assistance when they come up against intractable difficulties.

Extra Project

In addition to student-supervisor interaction, valuable support may also be available from other staff including technicians, computer officers and secretarial staff. The development of good communication by students with these staff should also be encouraged. Again, at the outset of the project, it should be made clear to students which staff are available and on what basis. Whether these staff can be approached at specific times, in what areas of the project they can assist and how often are all questions which should be clarified. Clear procedures should be put in place for students to request this assistance e.g. use of phone and fax facilities, manufacture of components in workshops, general technician support etc. Students should be made fully aware of the limitations of these resources, the importance of clear requests and instructions and benefits gained through polite enquiry. If students have difficulties in obtaining assistance, they should immediately inform their supervisor who should take the responsibility of resolving the problem directly with the support staff. It is unacceptable if students are told different things by academic supervisors and support staff and this situation should be avoided at all costs. Close communication between supervisor and support staff is therefore paramount. It is particularly important that students understand that support staff have many other duties (as do academic staff) and there will be limitations on their time. Support staff will be assisting on other projects and students should therefore accept that their project may not be top priority. Planning should take account of predictable delays arising as a result of support staff having to schedule their work.

The most obvious contact that students will have outside their project will be with other students (individuals or groups) working on similar or related projects. Discussion between students can be encouraged as this is the type of communication, which takes place naturally between engineers in the real world. However, supervisors should make it clear that, whereas discussion on technical and other issues is acceptable, the final design, product or component and report must be the work of the individual or group. Plagiarism should be treated very seriously and all students would be made fully aware of the penalties, which will result from using the work of others.

Communication with outside industry can be mainly for one of two reasons. Firstly, projects may be directly sponsored by a company or companies, which might supply funds, equipment and/or staff time and involvement. Under normal circumstances the supervisor will discuss and agree the basis of the collaboration with the industrial partner(s) before the outset of the project. From the student point of view it is important that the supervisor makes it clear the extent to which the individual or project team should be communicating with the sponsors. Some companies may have a major involvement, perhaps communicating on a weekly basis with the students, whereas in other cases, companies may just supply equipment or other one-off assistance. Students can gain useful communication skills whatever the level of collaboration, by learning to deal with engineers who, typically, are working under daily pressures from their main business. The difficulties associated with collaborators who will not fulfill promises, particularly in the timescales required, or who might put additional demands on students are all part of the learning process and the supervisor should be prepared to support students during the difficulties. It is the supervisor's responsibility to point out the possibilities of such difficulties arising and to ensure that time allowance is made for them. Some sponsored projects may have issues concerning

intellectual property rights (IPR) and students should be made fully aware of what they can and cannot discuss with third parties.

The second main reason for communicating with industry is to obtain information and advice relevant to the project, estimates or quotations for equipment or other work and to place orders for purchasing. The support, which might be required by students to contact suppliers, may include access to telephone, fax, stationery for letters and secretarial assistance. Procedures and arrangements for obtaining this support should be made clear at the start of the project as should the procedures for purchasing from suppliers, the completion of any necessary forms and approval procedures for expenditure. Often, the supervisor will deal with the latter.

Dissemination

A key area in the development of communication skills where students are likely to require significant support is in the planning, preparation and execution of written reports and verbal presentations. Tools should be provided for students to disseminate their results in the most professional manner practicable. Such tools might include word processing software for report writing, spreadsheet software for calculating and presenting tabulated results and presentation software for producing graphs and figures and for compiling slides for a verbal presentation. Integrated software, such as Microsoft Office (Word, Excel and PowerPoint) is ideal for students to prepare reports and presentations. Most students will be familiar with the use of such software through basic IT skills courses and general use in other areas of the curriculum.

For verbal presentations, students might require the use of a computer and data projector or more traditional materials such as overhead projector acetates and pens or photocopying facilities for producing acetates. Other items such as display boards, flip charts and 35 mm slide projectors may be needed. Supervisors should ensure that students are aware of what materials and equipment are available and whether there are any restrictions on use. Access to specific software for web-based presentations may also be required.

For written reports, students may require access to printing and/or photocopying facilities, to report binding equipment and word processing templates for title pages and general layout.

For both written reports and verbal presentations, written guidance notes should be provided to students. For written reports, these notes should cover details of report layout and extent, required length and detail in each section, acceptable formats for figures and tables and methods of referencing and bibliography citing. Details on resources available, on procedures for obtaining these resources and other support and on submission arrangements and assessment. Clearly, there may also be more project specific information e.g. collaboration with industrial sponsors, health and safety information etc. For verbal presentations, guidance on delivery techniques, available materials, use of software, expected audience and duration of presentations should all be included.

Management

Management of projects is a key skill all engineers should develop and the open-ended nature of many project-based learning activities provides an excellent environment for learning these skills. However, for students to gain best advantage from this environment, it is important that support is provided both in the form of introductory lectures on project management and as advice and close monitoring by the supervisor. Support for project management might include the teaching and provision of suitable tools and techniques for managing the project tasks within a specified timetable, advice on team management and dynamics and intervention when problems arise. In addition, the supervisor should support students in maintaining a culture of good record keeping and monitoring of project progress.

Project Planning

The supervisor should firstly ensure that students have a clear understanding of what they are aiming to achieve within the project. Without this, detailed planning will be fruitless. The students should then, through discussions with each other and the supervisor, adopt a task-centred approach to planning by defining individual tasks and setting realistic times for their completion. Although the supervisor will undoubtedly provide general advice, it is important that the students themselves undertake this planning process, as it is only through this exercise that an appreciation of the achievability and potential difficulties of completing tasks within the project can be attained. In addition to defining tasks, key milestones and deliverables should also be written down, again with a timing plan. Various tools and techniques are readily available for project planning and the supervisor should decide which are most appropriate, taking into account the scope of the project and the time available. PERT (Project evaluation and review technique) or CPM (Critical path methods) methods are more applicable to large scale projects with many interacting tasks and may not be suitable techniques for student projects. At a simple level, the students should be encouraged to use Gantt (or bar) charts to help define the project tasks and timescales for completion. These can then be reviewed on a regular basis at progress meetings and modified if necessary. Gantt charts can be produced very simply either by hand drawing or using standard word processing or spreadsheet software. Alternatively, if the project is sufficiently complex e.g. final year group project, it may be worthwhile introducing the students to specialist project planning software such as Microsoft Project.

Team Management

The supervisor has an important role to play in group projects by encouraging the development of an efficient team in which individuals communicate well with each other and support each other in their individual tasks. The correct choice of team leader is important and, although the supervisor may elect somebody, it is more common for the team to find its own natural leader, with perhaps some help from the supervisor through guided discussion. The supervisor should also get the team to think carefully and identify the strengths of individuals so that tasks can be allocated on the basis of these strengths. Team dynamics is also important and any split between members of the team should be avoided at all

costs. At all times, the supervisor should stress the importance of motivating and assisting each other to achieve both individual and group deliverables.

For individual projects the supervisor should encourage the student to accept responsibility for managing the project and progressing the tasks to a conclusion within the timescales agreed. It is most important that the supervisor reviews progress with the student on a regular basis (typically weekly) to ensure that this responsibility has been, and continues to be, accepted.

For group projects regular team meetings are important and the supervisor should insist that these take place at least weekly, but more often at the outset of a project and towards the end, when submission deadlines are approaching. Students should be told to keep a record of all meetings. This record should include details of those present, progress against previously agreed actions and new agreed actions for the next period. Any specific difficulties for the attention of the supervisor should also be recorded. The supervisor at group-supervisor meetings should inspect these records regularly. There may, of course, be additional requirements on record keeping such as individuals maintaining a logbook or laboratory notebook which may or may not be required at the conclusion of the project for assessment purposes. Other elements of record keeping, such as results recording and processing should also be inspected regularly by the supervisor.

At both individual and group meetings with the supervisor, similar meeting records should be maintained. The focus in this case should be on monitoring progress against the main tasks for the project and the checking off of milestones and deliverables.