Embedding Engineering Employability throughout a Curriculum Design Process

Dr Mike Knowles FHEA
Department of Computing, Engineering and Technology
University of Sunderland
About me....

• Senior Lecturer in Engineering
• Chartered Engineer
• Teaching since 2002 in various guises and at various guises and various institutions (Birmingham, OU, UoS)
• Programme Leader for FdSc Power Engineering and MSc Engineering Management
• Deputy chair of Faculty Quality Management Sub-committee
Background

• In 2015 Engineering programmes at the University of Sunderland underwent Periodic Review
• In previous years Microprocessors have featured as a 10 credit module delivered to second year Electronic and Electrical Engineering students – Approximately ten to twenty in number
• In the new programme structure this has become half of a 20 credit module with content on PLCs
• This module is now studied by students on all four* programmes.

Net Effect – rather than 15 students there are now approximately 80
Aspirations

• In addition to refreshing the technical content, I was keen to think more deeply about other aspects of the module
  • **Final Year Project preparation.** The final year project module is generally very successful, but one issue we grapple with is what students perceive projects to be in terms of approach and independence
  • **Graduate employability.** Employability is a key concern for all (engineering) programmes – but what does it actually mean?
Final Year Projects

• Empirical Observations as a Supervisor
  • Lack of appreciation of what a project is
  • Lack of clarity between project objectives and technical specifications
  • Understanding of the purpose of a literature review and background research
  • Discomfort when working independently with Technical Documentation

• Student Feedback
  • Requests for a prescriptive list of headings for report
  • More support for literature review/research elements
Employability Considerations

• “Many businesses feel that technical degrees do not develop practical skills, have insufficient depth, and are not up-to-date”
• Demand for Engineering Graduates outstrips supply
• This gap is underpinned by poor engagement with STEM subjects at school/FE

Institution of Engineering and Technology (2015)
Curriculum Design Engineering

• Traditional approaches to curriculum design focus on subject specific content - the technical material to be covered.
• Increasingly, however, the approaches to design and the standards against which engineering programmes are accredited focus on broader professional skills.
• While these generally align with the type of ‘transferrable skills’ found in many disciplines they are often specified in a Engineering focussed way
• Examples:
  • AHEP
  • CDIO
Professional Accreditation Standards: AHEP

Accreditation of Higher Education Programmes – Engineering Council documents which defines the skills and attributes which should be developed by HE Engineering programmes

Requirements include:

**Engineering Analysis**
- Understanding of, and the ability to apply, an integrated or systems approach to solving engineering problems

**Engineering Practice**
- Ability to apply relevant practical and laboratory skills
- Understanding of the use of technical literature and other information sources
- Ability to work with technical uncertainty
- Plan and carry out a personal programme of work, adjusting where appropriate

**Design**
- Investigate and define the problem
- Work with information that may be incomplete or uncertain and quantify the effect of this on the design
- Apply advanced problem-solving skills, technical knowledge and understanding, to establish rigorous and creative solutions

(Engineering Council 2014)
CDIO

• CDIO is an Engineering Syllabus developed at MIT with a focus on the development of problem solving skills

• Contains references to:
  • Engineering Reasoning and Problem Solving
    • Incomplete and ambiguous information
    • Problem solutions
    • Essential results of solutions and test data
    • Possible improvements in the problem solving process
  • Systems Thinking
    • Thinking Holistically- A system, its behaviour, and its elements
    • The important interfaces among elements
    • Tensions and factors to resolve through trade-offs
    • Solutions that balance various factors, resolve tensions and optimize the system as a whole
    • Possible improvements in the system thinking used
  • Conceiving Engineering Systems
    • System goals and requirements
    • System performance metrics

(Crawley 2001)
“Engineering Literacies”

• These requirements lead to the concept of a core set of underlying engineering literacies we aim to develop during the module:
  • Understanding the concept of “what a project is”
  • Designing with incomplete information
  • Engaging with technical documentation
  • Developing and implementing a testing methodology
  • Evaluation of the technical approach taken against alternatives
The Key Goals

• The key goals distilled from all of this analysis are:
  • to develop the students’ research skills coupled to self-assessment of the knowledge required to accomplish a particular task, leading to students gaining a greater insight into the role of technical documentation in engineering practice
  • to develop an understanding and appreciation of the benefits of following a logical approach to the entire lifecycle of a system development project.
Problem Based Learning

• Problem-Based Learning has been identified by many as conducive to developing employable graduates by developing students who:
  • Self-guided and independent
  • Able to manage their own knowledge and identify and address gaps relevant to a particular project

• But there are barriers to implementing “pure” PBL
  • Resourcing
  • Fitting constraints of timetabling
  • The need for individual assessment

• So can we embed and “blend” the strengths of PBL into a ‘traditional’ curriculum?
The curriculum design process...

• Based on the initial stages of that proposed by L. Dee Fink (2003)
• Involves the following stages:
  • Situational Factors
  • Learning Goals
  • Assessment Design
  • Learning Activities
## Step 1 - Situational Factors

<table>
<thead>
<tr>
<th>Category</th>
<th>Aspirations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Context</td>
<td>80 Stage 2 Students</td>
</tr>
<tr>
<td></td>
<td>1 hr Lecture, 1 hour lab in general computing facility</td>
</tr>
<tr>
<td>General Context</td>
<td>“Levelness” relative to FHEQ Accreditation requirements</td>
</tr>
<tr>
<td>Nature of the Subject</td>
<td>Technologically fast moving</td>
</tr>
<tr>
<td></td>
<td>Coupling between theoretical and practical elements</td>
</tr>
<tr>
<td>Characteristics of the</td>
<td>No previous knowledge – basic digital electronics only</td>
</tr>
<tr>
<td>Students</td>
<td>Potential apathy in non EE students</td>
</tr>
<tr>
<td>Characteristics of the</td>
<td>Industrial and research background</td>
</tr>
<tr>
<td>Teachers</td>
<td></td>
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</tbody>
</table>


## Step 2 - Learning Goals

<table>
<thead>
<tr>
<th>Category</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foundational knowledge</strong></td>
<td>Basic understanding of theoretical knowledge</td>
</tr>
<tr>
<td></td>
<td>Steps/technologies/approaches required to integrate a microprocessor/PLC into an application.</td>
</tr>
<tr>
<td><strong>Application Knowledge</strong></td>
<td>How to develop applications on the scale of FYPs</td>
</tr>
<tr>
<td></td>
<td>How to structure an Engineering project such as their FYP</td>
</tr>
<tr>
<td><strong>Integration Goals</strong></td>
<td>Link to basic digital topics covered in stage 1</td>
</tr>
<tr>
<td></td>
<td>Build on previous design project work</td>
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<tr>
<td></td>
<td>Achieve Integration within module (micros vs PLCs)</td>
</tr>
<tr>
<td><strong>Human dimension Goals</strong></td>
<td>Relevant aspects of team working for this subject</td>
</tr>
<tr>
<td><strong>Caring Goals</strong></td>
<td>Students develop an interest in the subject</td>
</tr>
<tr>
<td><strong>Learn-How-To-Learn Goals</strong></td>
<td>Students should become more familiar with the use of datasheets and other similar documentation.</td>
</tr>
</tbody>
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Step 3 – Procedures for Educatve Assessments

<table>
<thead>
<tr>
<th>Criteria</th>
<th></th>
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<tbody>
<tr>
<td>Forward Looking Assessment</td>
<td>Assessments replicate future applications – i.e. ability to apply the technology in a project involving selection of components and programming approach, design process, testing etc. Exam focus on decision making and justification rather than abstract analysis and regurgitation</td>
</tr>
<tr>
<td>Criteria and Standards</td>
<td>Assessments measure ability to apply knowledge in an application context by creating programs and understanding applications</td>
</tr>
<tr>
<td>Self Assessment</td>
<td>Embed self-assessment into laboratory sessions in terms of success of design work and preparatory work</td>
</tr>
<tr>
<td>FIDELity Feedback</td>
<td><em>i.e Frequent, Immediate, Descriminating, Lovingly Delivered.</em> “Personal Tutoring” approach to delivery in lab sessions</td>
</tr>
</tbody>
</table>
## Step 4 – Learning Activities

<table>
<thead>
<tr>
<th>Getting information and ideas</th>
<th>Experience</th>
<th>Reflective Dialogue</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Doing</td>
<td>Self</td>
</tr>
<tr>
<td></td>
<td>Observing</td>
<td></td>
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<tr>
<td><strong>Direct</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary data collection, self-guided</td>
<td>Laboratory sessions where programmes must be developed</td>
<td>Laboratory Sessions where code is given</td>
</tr>
<tr>
<td><strong>Indirect, Vicarious</strong></td>
<td>Lectures, Textbooks, Datasheets</td>
<td>Case Studies, “Structured Examples”</td>
</tr>
<tr>
<td><strong>Online</strong></td>
<td>VLE, Datasheets, Own Research</td>
<td>Online Simulation?</td>
</tr>
<tr>
<td>Learning Goals for Course</td>
<td>Ways of Assessing this Kind of Learning</td>
<td>Actual Teaching-Learning Activities</td>
</tr>
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<td>----------------------------------------------------------------------------------------</td>
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</tbody>
</table>
| Technical/Theoretical Knowledge of Micros/PLCs and their application                    | ‘Old fashioned’ Exam Application of this knowledge in labs/assignment                                   | Lectures  
Self-study set between lectures  
Use in labs                                                                 | Datasheets – set exercises after lecture to identify some piece of info from theory in the material covered in lecture?? |
| Knowledge of how to apply micros/PLCs in a piece of project work                        | Assignment to include application of micros/PLCs                                                      | Assignment supported by the lab sessions.                                                           | “Structured Examples”  
Case studies                                                                               |
| How to approach piece of project work                                                   | Assignment to encapsulate the entire project process include specifications,  
research and evaluation                                                                                   | Assignment acting as a guide for the structure                                                    | Material from FYP handbook??                                                      |
| Application of first year fundamental skills                                            | Exam questions – use elements of micro from datasheet to ask questions that involve this.  
Signal conditioning elements of assignment/exam                                                   | Lectures – incorporate this into theoretical coverage of key elements e.g. ports  
This could also be done with coverage of number systems, using lectures to form a link between first year stuff and programming  
Design activities in labs – simulation to verify designs and check voltages etc at various points | Data sheet materials  
RLO on number systems and addition  
Proteus Simulation Software                                                                   |
| Ability to work with technical documentation                                           | Use extracts in exam questions  
Embed the need to engage with technical documentation in assignment                                    | Set structured ‘self study’ exercises after particular lectures to build towards the more advanced laboratory exercises | Datasheets                                                                      |
So what does this mean in practice?

- Constraints of resources:
  - One hour per week of “lectures”
  - One hour per week of “practical work”
- Practical activities with decreasing levels of guidance
- Start with directed guidance on preparatory research
- Zero tolerance (threatened...) for students with no evidence of preparation
- Structured demonstrations in lecture sessions
- Planned inter-lecture research activities to support and integrate lecture and practical sessions
- Project based assignment requiring integrative knowledge on all topics within the module
Delivery

• Lectures:
  • Align with laboratory work
  • Set reading and preparatory work based on lectures to support practical sessions
  • Check it has been done!!

• Lab:
  • Give a fully working basic programme to begin with to support rapid early progress and to facilitate observation of working programmes
  • Use this as a ‘template’ to build future increasingly complex programmes with diminishing levels of guidance to reinforce the need for design and preparation
Assessment

• Written Exam – 50%
  • NO CODING!!!
  • Elements of interpreting technical material
  • Focus on making and understanding technical decision making.

• Assignment – 50%
  • Scenario – control of greenhouse environmental control for cultivating tomatoes
  • Fairly typical problem but traditionally assessments such as this would focus purely on the ‘technical ‘ aspects and less on the process
  • In reality it is the process that is significant – NOT the tomatoes!
  • “Staged” approach to support development of awareness of project working skills
Assignment Elements

• Report (80%)
• Research on functional requirements for system (10%).
• Selection of appropriate sensors (10%)
• Selection of a suitable Microcontroller (10%)
• Design of the Microprocessor and PLC programs to meet the above specification (20%)
• Evaluation of all system elements and a proposed structure to include all external elements of the control system (20%)
• Design and simulation of signal conditioning systems (10%)
• Lab Demonstration (20%)
• Creation and validation of Microcontroller Program (10%)
• Creation and validation of PLC software (10%)
Observations so far...

• Students not expecting this type of delivery
• “When are you going to teach us how to do this?”
• Lack of note taking in structured demonstration – the expectation that material will be instantly shared on the VLE leads to complacency and encourages a superficial approach to learning in these sessions.
• One hour at a time for practical work is limiting
Future directions...

• Enhance the level of contextualisation in the lab sessions to improve engagement

• Development of more robust hardware

• Revisit and enhance timetabling
  • Fewer, longer lab sessions?
  • Blend use of general purpose computer suites with specialist lab facilities

• Refine module schedule to better tie in between classroom sessions and practical sessions

• Consider how to enhance the assignment by providing the opportunity for more structured testing and evaluation – use of a ‘test rig’?
Conclusions

• By considering “hidden” non-technical considerations from the outset it is relatively easy to embed the development of some of the broader, employability based skills:
  • Enhanced awareness of project work
  • Independence
  • The ability to make design choices using incomplete information
  • The ability to carry out research to support a solution

• Early considerations allows these skills to be embedded within technical modules even under practical constraints.
References


