Product re-engineering for enhanced end-of-life performance

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1) Abstract

Starting from the year 2010, students of The Open University who enrol on the Level 5 (Level 9 in Scotland) residential school module *Engineering in Action* have undertaken a team project focused on end-of-life product design. This subject is of key importance in the context of the engineer's role in sustainability, which is now a feature of all engineering programmes. The team aspect of the project also provides an important opportunity for skills development for students who normally work alone and at a distance.

The project is divided into three sessions spread across the residential school week:

Session 1 acts as a team forming and icebreaker activity and is centred on dismantling of an item of waste electrical or electronic equipment (WEEE) to enable critical analysis of its design and manufacture.

Session 2 is aimed at gathering information on design for manufacture and assembly and design for end-of-life, the waste recovery and recycling industry, and the legislative framework for WEEE. This information is used by the students as a basis for proposals for design improvements to their product to improve its end-of-life performance.

Session 3 culminates in a short poster presentation by the student teams.

Students are provided with preparatory material, which they study before attending the residential week, and notes and instructions at residential school that cover what they are expected to achieve in the three sessions. There is also additional supporting material provided through a module website, including full access to the Open University online library.

The activity is facilitated by part-time teaching staff (tutors) who are contracted for the duration of the residential week alone, working to guidance provided by the *Engineering in Action* module team.

The 2010 cohort of students (around 150 in number) were invited to complete evaluation questionnaires and to volunteer for a follow-up telephone interview. Questionnaires were also distributed to the 16 tutors. Further tutor feedback was obtained from direct discussions during the residential school.

The outcome of the evaluation was overwhelmingly supportive of the design and delivery of the new team project. Suggestions for improvements were received but none requiring significant alteration of the project. Many of these were implemented for the 2011 presentation and a number are being considered for future presentations.

2) Background

Residential schools have been a feature of Open University provision since its establishment in the early 1970s. From the earliest times, students in all disciplines were expected to attend for one week full time at the campus of a conventional university during most years of their study programme. The timetable for such weeks is organised around the students arriving on site during Saturday, beginning the academic programme on Saturday evening and finishing the programme around midday on Friday. There is generally a half-day break on Tuesday. That provides four full days – Sunday, Monday, Wednesday and Thursday. The remaining sessions are Saturday evening, Tuesday morning and Friday morning.

Engineering in Action was first presented in 2004. The module was an adaptation of the longstanding and successful residential schools from two earlier modules, *Engineering Mechanics: Solids* and *Materials: Engineering and Science*. Three day-long activities were taken from these two schools to form the majority of the student activity. A fourth was developed from scratch and the four activities were scheduled to take place on the four full days of the timetable, Sunday, Monday, Wednesday and Thursday. The remaining sessions were linked together into a formal group project, for the first time. This was based around an exploratory approach to chocolate and a design activity for a new chocolate-based product, which the teams presented at the end of the final session.

At the end of 2009, a Level 4 (Level 7 in Scotland) residential school module formerly administered by a different programme was withdrawn. The resulting gap in the curriculum was taken over by the Engineering Programme with a new residential school, *Engineering: an Active Introduction*. The model adopted for this new school was the one developed in 2004 for *Engineering in Action*. Following extensive discussions, it was decided to transfer the team project activity from the Level 5 school to that at Level 4. This required a new team project to be developed for *Engineering in Action*.

3) Overview of Project

The project was designed to delivery explicit team working and communication skills based on the framework developed earlier. To distinguish the activity from that which had been ‘cascaded’ to Level 4, it was decided to use a different mode of presentation. A poster presentation was adopted as complementary to the Level 4 activity involving a more formal presentation with overhead projector slides.

The other important development was specific focus on sustainability, a subject which students encounter in their Level 4 studies although the role of the engineer in contributing to sustainability is not much emphasised there.

A key feature of the activity design was engaging students’ interest by the physical means of dismantling products. Some pundits (Crawley et al, 2007) claim that this kind of physical activity has been lost from engineering education in the recent past, to the detriment of the student experience.

Design of the activity

The following extract from the *Tutor Notes* summarises the new activity.

> *The idea behind the activity is to explore a small part of a very real problem – how to deal effectively with the waste stream from end-of-life products. It has been quite deliberately designed to resonate with the deep-seated urge felt by many (or even most) engineering students to take things apart. For once, students can be told simply to get stuck in!*
>
> *What we want our students to do is develop designs that have better eol performance. Taking something apart allows them to find out how the product they choose to work with was assembled and why it was designed to be assembled in that way. They can then combine this knowledge with their own experience of dismantling the product to propose design improvements for a product that is easier to dismantle and whose parts can be better reused or recycled.*
>
> *Above all, in this activity, we want students to take responsibility for organizing themselves to achieve the goals that have been set for them. [The tutor's] role is, of course, to support the 'technical' work the students need to do but it is even more important to help them organise and undertake their work so that they arrive at a satisfactory outcome having both* **had fun and learnt something**.

Prior to arrival at the residential school, each student is provided with activity specific study material. This contextual material covers waste and resource management, management of waste electrical and electronic equipment (WEEE), design and manufacturing, recycling of metals and recycling of plastics. On arrival at residential school, the student receives a set of instructions for the activity. These only state the tasks and guidance on the types of activities required to complete them and an outline time-table. (Work scheduling, task allocations and prioritisation are not defined as these are intended to be a core team organisation task.)

The following extract from the *Student Notes* provides the structure of the activity.

> *The activity itself is spread over three residential school sessions:*
>
> 1. *On Saturday evening you will choose a product and, working in a small team, dismantle it and examine it in a lot more detail. Your team will give a brief presentation about your product to your tutor group.*
> 2. *On Tuesday morning your team will investigate further how to extract value from your product at the end of its life and balance this against the cost of its recovery and disposal. You will research the various laws governing what happens to such a product once it enters the 'waste stream' and you will start to formulate a plan to redesign part of your product to improve the balance of value to cost at end of life (eol).*
> 3. *On Friday morning you will finalize your proposals and make a short presentation, as a team, to your assembled tutor group.*

The intended learning outcomes for the activity articulate directly with the UK-SPEC learning outcomes for accredited engineering programmes (Engineering Council, 2010). They are the development and demonstration of:

A A basic knowledge and understanding of:

1. The materials used in the construction of typical small domestic appliances
2. The methods used to assemble these appliances
3. The regulations relating to the disposal of products at the end of their useful lives

4. How domestic appliances could be designed and assembled in order to maximise the potential for reusing and recycling the components and materials at the end of the appliance's life.

B The ability to:

5. Work as part of a team to achieve a common goal
6. Obtain information on how a product is manufactured by dismantling the product
7. Record this information using qualitative and quantitative methods
8. Propose design changes to improve the product's performance in a given respect based on analysis of the information gathered
9. Plan and deliver a presentation of work in a given format.

Relevant resources are provided during the sessions: tools, product assessment equipment, computers with access to relevant information databases and templates and drawing equipment for creating presentation posters.

The format chosen for the Session 3 presentations was derived from that of the conference poster. The posters themselves are simple, hand-drawn displays on A2-sized sheets. Each student is instructed to prepare a single sheet, the team's sheets together making up the full team presentation. As the last part of Session 3, each student team in turn must make a 10-minute presentation of their investigation and design proposals.

The role of the tutor

The student body is sub-divided into groups of around 20, each of which is allocated two tutors. The tutors themselves are appointed from full-time Open University staff or are contracted in as part-time staff just for the duration of the residential week. Each tutor is provided with briefing notes outlining their role and providing help and guidance on facilitating the students' work.

The tutor provides a briefing at the start of each session. His or her role is to promote good time management and provide moderate levels of guidance for the technical tasks such as product dismantling in Session 1 or poster preparation in Session 3. The tutors also monitor the level of engagement of the students in the activity and, at the end of Session 3, complete an assessment sheet for each student.

4) Impact on academic practice – e.g. *changes to teaching practice; redesign of modules; multiple group teaching; effect of changes to technical support; potential impact; benefit to students.*

5) Difficulties encountered

The limited time available within the activity, and outside it but within the week, coupled with the diverse backgrounds of the student cohort, biased us against adopting IT approaches to the group presentation. The default remains hand-drawn posters. However, students generally realise that they can use the computers and colour printers we provide to produce images and text in a way that contributes significantly to the visual appeal of their materials. Examples of this can be seen in the attached illustrations.

The one major challenge to providing a rewarding student learning experience will always be securing a supply of appropriate WEEE. For the purposes of *Engineering in Action*, this

amounts in 2013 to over 100 separate items of a suitable design that students can realistically undertake the activity. We have addressed this through our work infrastructure, encouraging and regularly reminding colleagues across the whole of the University to donate their WEEE to a central collection point on campus in Milton Keynes. This is then sorted and grouped into sets – one per tutor group per week – for delivery to the residential school site.

6) Benefits

A small project grant was obtained from UKCME in 2010/11 to conduct an evaluation of the effectiveness of the project in achieving its objectives, from the perspective both of students and tutors. The detailed results of this evaluation have been reported in Endean et al (2012). Taken together, the evaluative feedback confirmed:

1. the initial premise used in designing the module (engineers are hands-on and wish to get stuck in) and
2. the need for the activity to include a mandatory presentation so as to nurture and develop essential professional skills during an engineer's formal education.

Tutor feedback was overwhelmingly positive and tutors were actively engaged both in facilitating the activity and in providing constructive feedback on its design and implementation.

No feedback obtained, either through immediate, informal comments during and after the residential school or through the evaluation conducted as part of this study, suggested a need for any radical change to the activity. Various minor improvements were suggested and discussed and a number of these were implemented for the 2011 presentation.

7) Advice to others

Sufficient detail of the team project is available on request for it to be implemented in other institutions. This includes tutor notes, student notes, equipment lists and timetables.

Finding suitable WEEE is a matter of experience and context. The OU context favours small electromechanical devices such as toasters, hairdryers, kettles etc. and can extend to simple printers, keyboards and landline telephones. More complex products, such as digital cameras or DVD players, may be suitable where the timetable for dismantling and 'reverse engineering' can be extended. Students are not keen on what they see as 'obsolete' products.

The success of the project may well be partly due to contextual factors, such as student demographics, the role of residential schools within the Open University programme and the timescale over which the project is delivered. We hope to learn more from the experience of other educators.

8) Future Plans

The overall framework within which the activity is designed remains sound, as does the activity itself. Although there are no immediate plans for anything more than an annual review by staff of effectiveness, it would be possible to develop new activities within the same framework.

9) References

Crawley, E., Malmqvist, J., Ostlund, S. and Brodeur, D. (2007) *Rethinking Engineering Education – The CDIO Approach*, Springer Science + Business Media, New York.

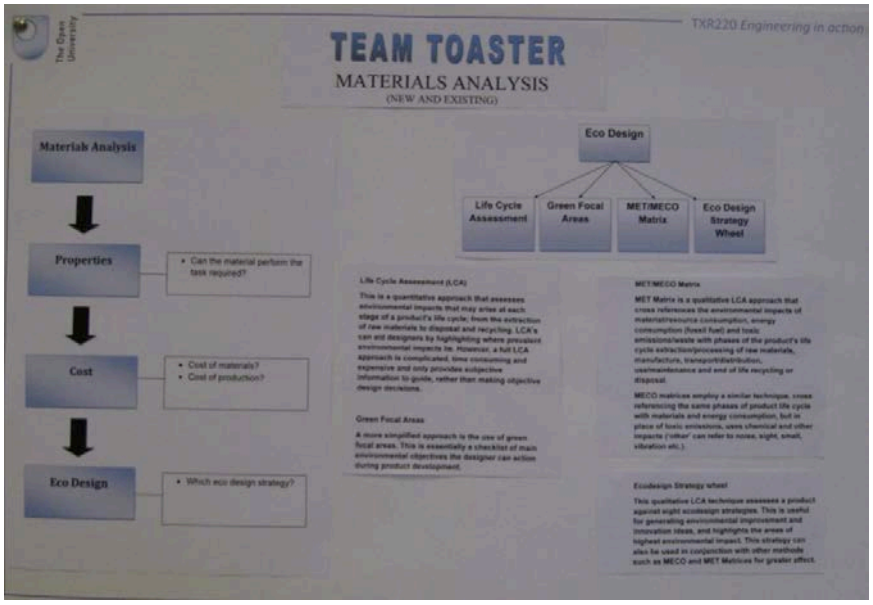
Endean, Mark; Clay, Kath and Burnley, Stephen (2012). Evaluation of residential school activity 'Product re-engineering for enhanced end-of-life performance. In: *Engineering Education 2012*, 18-20 September 2012, Coventry.

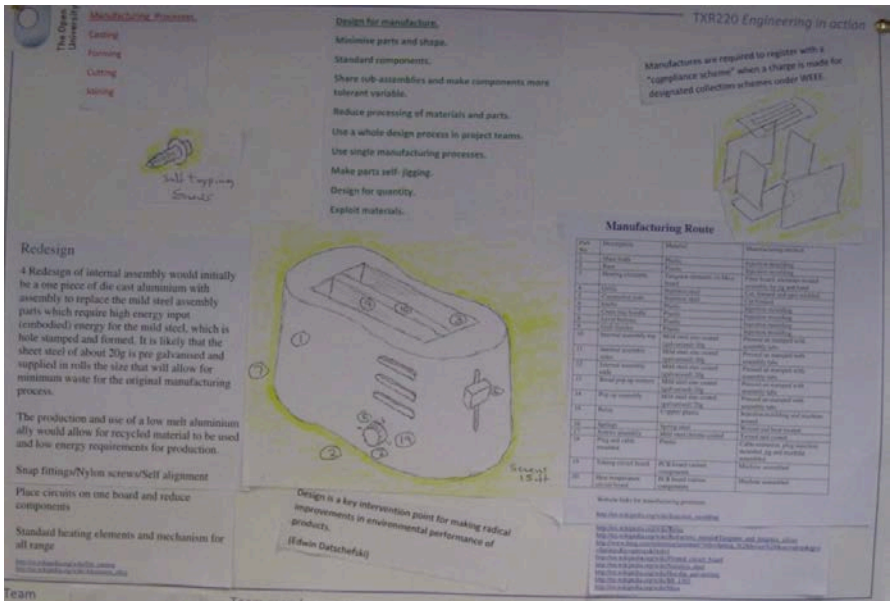
Engineering Council (2010) *The accreditation of higher education programmes* Engineering Council for the UK, London.

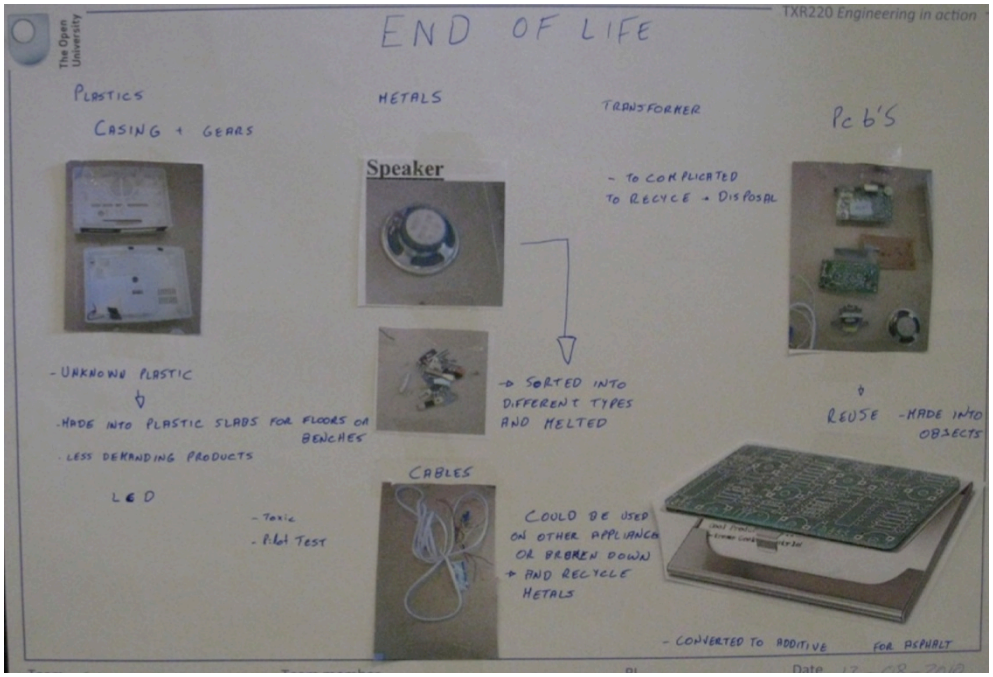
10) Sample images

Illustrations of students at work are available but cannot be included here without formal permission from the students.

Below are some samples of student posters.



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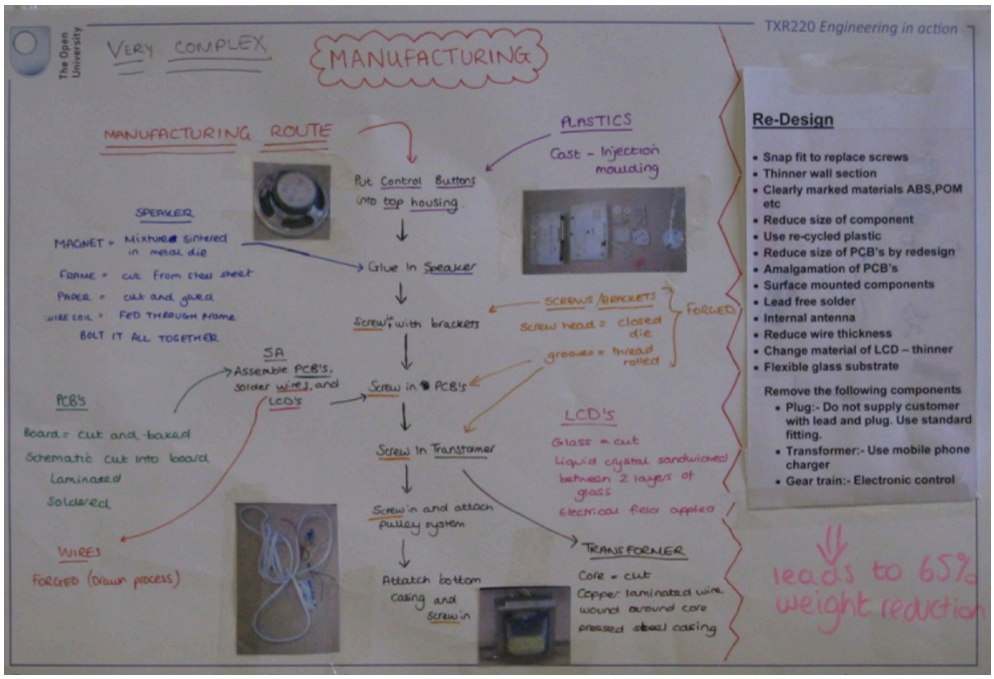
TXR220 Engineering in action
END OF LIFE
PLASTICS
CASING + GEARS
METALS
TRANSFORMER
PCB'S
Speaker
- TO COMPLICATED TO RECYCLE → DISPOSAL
- UNKNOWN PLASTIC
↓
- MADE INTO PLASTIC SLABS FOR FLOORS OR BENCHES
- LESS DEMANDING PRODUCTS
LED
- Toxic
- Pilot Test
CABLES
→ SORTED INTO DIFFERENT TYPES AND MELTED
COULD BE USED ON OTHER APPLIANCES OR BROKEN DOWN → AND RECYCLE METALS
↓
REUSE - MADE INTO OBJECTS
- CONVERTED TO ADDITIVE FOR REPAIR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TXR220 Engineering in action
VERY COMPLEX
MANUFACTURING
MANUFACTURING ROUTE
SPEAKER
MAGNET = Mixture sintered in metal die
FRAME = cut from steel sheet
PAPER = cut and glued
WIRE COIL = FED THROUGH FRAME
BOLT IT ALL TOGETHER
PCB's
Board = cut and baked
Schematic cut into board
Laminated
Soldered
WIRES
FORGED (Drawn process)
Put Control Buttons into top housing.
Glue in Speaker
Screw in with brackets
SA
Assemble PCB's, solder wires, and LCD's
Screw in PCB's
Screw in Transformer
Screw in and attach pulley system
Attatch bottom casing and screw in
PLASTICS
Cast - Injection moulding
SCREWS/BRACKETS
Screw head = closed die
groove = thread rolled
FORGED
LCD'S
Glass = cut
Liquid crystal sandwiched between 2 layers of glass
Electrical field applied
TRANSFORMER
Core = cut
Copper laminated wire wound around core
pressed steel casing
Re-Design
Snap fit to replace screws
Thinner wall section
Clearly marked materials ABS,POM etc
Reduce size of component
Use re-cycled plastic
Reduce size of PCB's by redesign
Amalgamation of PCB's
Surface mounted components
Lead free solder
Internal antenna
Reduce wire thickness
Change material of LCD – thinner
Flexible glass substrate
Remove the following components
Plug:- Do not supply customer with lead and plug. Use standard fitting.
Transformer:- Use mobile phone charger
Gear train:- Electronic control
leads to 65% weight reduction