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Evaluation of residential school activity 'Product re-engineering for enhanced end-of-life performance'

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***Abstract**: Starting from the year 2010, students of The Open University who enroll on the residential school module Engineering in Action have undertaken a team project focused on end-of-life product design. This highlights the engineer's role in promoting sustainable futures, 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.*

A key aspect of the design of the activity is the use of genuine end-of-life domestic products to engage the students' interest and motivate them to find out more about the product by linking their investigation to their everyday experience.

Small project grant funding was obtained in 2010 from the UK Centre for Materials Education (UKCME) to study the effectiveness of the activity in terms of student and staff satisfaction and the quality of the student learning experience.

The 2010 cohort of students (around 150 in number) were invited to complete evaluation questionnaires and to volunteer for a telephone interview. A total of 126 completed student questionnaires were received and five students were subsequently interviewed. Questionnaires were also distributed to 16 tutors and four were completed and returned. 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.

The success of the project may 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. This possibility remains to be tested by other educators.

Background to this study

A new student team activity has been introduced into the Open University residential school module TXR220, *Engineering in Action* (10 credits, FHEQ Level 5).

The new activity was delivered for the first time in August 2010, to a total of around 150 students divided equally between two separate residential school weeks, engaging 16 staff in direct teaching roles.

Over the course of three separate sessions in the week, students investigated how the design of a small electrical/electronic product impacts on its performance at end-of-life (eol). The students worked towards a proposal for redesigning the product to improve its eol performance. The three sessions provided a core team-working thread to the school, spread throughout a week dominated by more conventional laboratory-based activities.

The student activity itself is of significance as it connects product design very firmly with issues of ethics and sustainability. It is pitched in such a way that it can be used with engineering students of all levels, from university entry through to postgraduate. The design of the activity resonates with some of the deep-seated drives that all engineering students share and is therefore potentially highly motivating, linking the effectiveness of the activity with issues of student motivation, a subject of increasing concern in engineering education.

The aim of this research study was to evaluate the effectiveness of the activity both in terms of engaging the students' interest as well as in pedagogical terms.

Background to the activity

Engineering in Action was one of the earliest Open University modules to be presented as a standalone residential school and was an adaptation of residential schools 'embedded' in two earlier modules, one focused on engineering mechanics and the other materials engineering.. 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. The remaining sessions, an evening and two mornings, were allocated to a team project.

The following extract from the *Engineering in Action* Tutor Notes summarises the team project.

> 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 [eol] 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***.

Design of the activity

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 (LOs) 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.

Table 1 shows how these LOs are linked to tasks within the activity's three sessions.

Table 1: Links between Module Learning Outcomes and Activity Tasks

Learning Outcome	Pre- Residential School Study	Session 1	Session 2	Session 3
1	✓	✓	✓	
2	✓	✓		
3	✓		✓	
4	✓		✓	
5		✓	✓	✓
6		✓		
7		✓	✓	✓
8			✓	✓
9				✓

Prior to arrival at the residential school, each student is provided with activity specific study material (part of the residential school preparatory handbook). 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 timetable. (Work scheduling, task allocations and prioritisation are not defined, as these are intended to be a core team organisation task.)

The residential school activity is split into 3 sessions: an initial 2 hour session (session 1, Saturday evening) followed by two 3.5 hour sessions (sessions 2 and 3 on Tuesday and Friday mornings respectively).

The content of the sessions is outlined in Table 2.

Table 2: The three activity sessions

	Brief	Activities
Session 1	Working in a small team of 3 to 5 students, choose a (used small electrical/electronic) product, dismantle it and examine it in detail. Give a brief team presentation about the product to the group.	Practical disassembly of product to produce qualitative and quantitative records of: inventory, product construction, material, product assembly, product disassembly instructions.
Session 2	Investigate how to extract value from the product at the end of its life and balance proposals against the cost of its recovery and disposal. Formulate plan(s) for re-designing part of the product to improve balance of its value to cost at end of life (eol).	Research (using information searches) the various laws governing what happens to such a product once it enters the 'waste stream'; location of relevant information to support re-design proposal.
Session 3	Finalize re-design proposal, present team poster on product and its re-design to assembled group.	Definition of re-design; preparation of visual and oral material for 10-minute poster presentation; team delivery of presentation.

Products available for selection by teams during the first presentations were drawn directly from the WEEE stream and provided by Bath University, the host site for the residential school. Available for selection by students were a broad variety of products including: cassette player/recorder, computer modem, inkjet printer, hair dryer, telephone (land line both fixed and cordless), kettle, toaster, clock radio.

Allocation of students to teams is not managed by staff. The students are not normally known to each other before arrival at the first session, when they are instructed to organise themselves into four teams (i.e. four to five in each team). Similarly there is no attempt to allocate roles within the team.

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. In the absence, however, of sophisticated display preparation facilities and the time to learn to use them, 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 assess each student in terms of active participation.

Evaluation

Objectives

The evaluation targets were defined by the following research questions:

1. What were the levels of student motivation and engagement with the tasks/activity?
2. How effective was the practical delivery of the activity?
3. Did the activity achieve its learning outcomes?
4. How did the tutors respond to the activity?

Methods

Surveys of students were used as a method of obtaining an overview of their engagement and participation. The other research questions required a mixture of qualitative and semi-quantitative information so use of direct survey instruments along with the grounded theory approach for data analysis was appropriate (Strauss and Corbin, 1990). The guidance available on the efficacy of different survey methods within the field of human-computer interaction (Adams et al, 2008) pointed to the use of a questionnaire followed by individual in-depth structured interviews. In addition the final research question was addressed by a survey of participating tutors.

The prime researcher (Kath Clay) also observed all activity sessions during one week of the residential school and resulting observation notes were treated as data within the evaluation.

All surveys complied with the ethics guidance and consultation protocol and regulations of The Open University. The survey instruments and interview protocols are available on request from the authors along with a detailed breakdown of the results obtained.

Student Questionnaire

A student residential school exit questionnaire, used to obtain quantitative data, comprised opinion and attitudinal question types. Likert format and scales were used for ten questions which specifically explored student engagement both prior to and during the activity (research question 1). A study population of 126 was achieved from a student sample size of 148 (85% return).

Student Semi-Structured In-Depth Interviews

Student interviews had the function of exploring many of the opinion and attitudinal questions within the module exit questionnaire and also generating data appropriate to other research questions. Using an interview structure plan (of a format recommended by Adams and Cox, 2008) a total of 5 telephone interviews were completed during September to November 2010. All interviewees were randomly selected from the 40 eligible volunteers identified in the residential school exit survey. All interviews (each approximate 20 minutes long) were recorded and transcribed.

Tutor Questionnaire

Tutors response to the module was obtained by a questionnaire. This contained only factual questions which explored the effectiveness of tasks within the activity, activity management and improvement suggestions relating to both these areas. A small study population of 4 was achieved from a tutor sample size of 16. However, additional data from the prime researcher's observation notes were also included.

Findings

Quality of student experience.

Two aspects relating to the student experience were identified as key factors; these are also generic issues of concern within both The Open University engineering discipline and the wider Engineering Education community. They are student motivation and engagement.

Individual Motivation and Engagement.

Students were already engaged in the task on arrival at residential school: just over 80% (48% definitely agreed (DA) and 34% mostly agreed (MA)) of the study population had studied the activity's preparatory material. Of these, 86% agreed that it provided adequate preparation for the activity's challenges. This is further supported by activity satisfaction ratings as two thirds (27% DA, 40% MA) of the study population indicated satisfaction. Within the student interviews, the dismantling of the product was identified as a highly enjoyable activity. As it is the first task, it appeared to be a key motivator for early engagement with the activity.

The tutors noted the high quality of posters and presentations, with no recorded student defaulters for this task. This provides further evidence that student motivation and engagement was retained throughout the activity. Furthermore, the general comments offered by the student interviewees were all positive regarding the activity, indicating clear engagement in a constructive learning experience. In particular, one respondent noted enjoyment of the realism of the activity due to the use of real products.

Engagement in Team Working.

Over four fifths (54% DA, 31%MA) of the student population enjoyed the team working experience. Interpreting enjoyment as positive engagement, this is a very good outcome for the activity and an indicator of overall clear achievement of the learning outcome: 'work as part of a team to achieve a common goal'. Good and enhanced team working engagement was noted in student interviews where attitudes to team (or group) work both pre- and post-residential school were explored. Most of the cases where pre-event doubts concerning group working existed had more positive views on team working post-event. One such interviewee noted enjoyment of 'the inspiration of working in a group'.

A tutor comment noted features of the activity's structure that enforced teamwork, namely 'there is a lot to do in the Saturday evening session (Session 1)…recommend retain the ambitious list of things to do…as it encourages all students to participate and engage with their group at an early stage'.

Also the activity is 'a good exercise in teamwork (as the complex task could not be accomplished by an individual in the time available)'. The general coherency achieved within the poster presentations (both oral and visual) is also considered an indicator of good team engagement by students within the activity.

The student interviews also provided information on the team organisation and dynamics. Team roles and responsibilities appear to have been established within Session 1. One example where satisfactory team dynamics were not established in the first session was highlighted, but this issue was resolved by the team at the start of Session 2. However, this one, apparently isolated, case not only exemplifies team development and maturation but probably demonstrates the benefit of having the time spread between the activity sessions as well. The time separation allows students to become more comfortable both with their peers and with the residential school's expectations as it progresses.

Individual contributions to team progress cannot be generalised, as students all have individual talents and limitations. Within the student interviewee cohort of 5, when asked to explain the most and least enjoyable aspects of the Activity A experience, a range of answers were offered. Although this is a very small sample size, product dismantling and poster presentation appear as the most and least enjoyable aspects respectively. These findings confirm:

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.

Effectiveness of delivery of the activity.

Four main factors had the potential to significantly influence the delivery of the activity: the written instructions, the products investigated, resources available, and the support provided by tutors.

Written Instructions

As noted earlier 69% of the total student study population indicated that they found the preparatory material useful. Further, one student interviewee in particular noted that the preparatory information's technical reviews were 'a good source of keywords for information searching during actual activity sessions.' So, the conclusion is that they enhanced activity delivery, where used.

The second set of documents is the written briefs issued to the students during the actual sessions. Student reactions to them were only captured in the interviews. These were all positive with regard to the documents' structure and format, e.g. 'provided a good clear frame (work) of the activities (tasks) required to meet the activity's goals'. Also, the timetabling guidelines were noted to be helpful. One tutor also reflected that they contained a good balance between guidance and freedom of action. Furthermore, another tutor commented that having combined student briefing notes for sessions 2 and 3 was beneficial to students as it scoped the whole task for them and allowed for team forward

planning for the bulk of Activity A. This is an important contribution to achievement of learning outcome 5: demanding time constraints provide an effective learning experience.

The final document set is the briefs for tutors. Although the levels of detail within them appeared adequate, they were supported by daily briefs by the Residential School Academic Chair. These are documents that will need to evolve to incorporate refined practices as tutors become more experienced with supporting the activity. Suggestions for improvement included adjustments to the timetable to allow more time for the poster presentations and enhancements to the information resources to support Session 2.

Products

Of the products available to this cohort, tutors reported that these all had, firstly, sufficient complexity to engage and challenge all members of a 4 to 5 person team and secondly, sufficient diversity of re-engineering possibilities aligned with the activity's technical/knowledge acquisition objectives (learning outcomes 1 to 4). CD and DVD players (both static and portable) and an electric iron emerged as further suggestions from the tutor survey.

Resources

The supplied resources, namely tools, product assessment equipment, computers with access to relevant information databases, and templates and drawing equipment for creating presentation posters, appeared adequate for the tasks within the activity (as all groups completed and student declared themselves overwhelmingly satisfied with the total learning experience). However, as expected with the first deliveries of any new learning experience, additional resources were identified as desirable by students, tutors and observer alike. These are listed below.

Tutor Support

Over 80% (41% DA, 41% MA) of the student survey population noted satisfaction with the quality of tuition and guidance throughout the activity. Student comments in interviews indicate that tutors generally allowed teams to develop and solve problems as a team, and only directly intervened technically when requested although they would ask perceptive questions when necessary. This corroborates the recommended role of tutor as facilitator to the team work rather than in a didactic or pedagogical role.

Tutor support was identified as more proactive by interviewees in two areas, namely reminders of time management deadlines and instruction in the format and characteristics of an academic poster presentation (a deliberate support intervention as a poster format was expected to be unfamiliar to most students).

A final factor in the effectiveness of delivery, difficult to define but easier to assess, is the pace of the activity. A balance needed to be struck between too high a pace (that could dilute the student learning experience) and too low a pace that would preclude parallel working within a team. Quantitative measures from the student questionnaire indicated no majority consensus regarding both the pace and workload for the activity.

Academic (learning outcome) goals

The learning outcomes for the activity are set out above.

The activity exit survey revealed a 76% (28% DA and 48% MA) agreement that learning outcomes were achieved. However, as reflection can be influenced by time separation from the learning experience, a repeat of the question during interview, during which all learning outcomes were described individually, revealed unanimous agreement that all were achieved.

Objective (external) measures that the activity met some academic goals (LOs 5 and 9) can be provided from module records that all students participated in the team activity, and the preparation and delivery of a poster presentation. A peripheral observation from the student interviews is that the later activity, directly linked to learning outcome 9 (plan and deliver a presentation of work in a given format), was one of its most challenging yet rewarding tasks. It was not enjoyed by only 13% of the questionnaire's study population whereas 66% (30% DA, 36% MA) noted enjoyment of the group presentation experience.

Tutor Experience

The final research question 'How did the tutors respond to the activity?' is one that requires a consideration not only of responses to many questions within the tutor survey but, equally importantly, of the observations of the prime researcher. The latter noted that the tutors seemed genuinely interested in the content of the activity and comfortable with the tasks and the level and style of direction/teaching expected from them – that of facilitator. They also had the opportunity to get to know the same cohort of students within the residential activity and so were able to identify students who needed specific counselling and encouragement for the presentation task.

This view was corroborated by the survey feedback and follow-up interviews:

> Especially good is distribution of sessions 2 and 3 scripts / information together so that students are free to organise themselves to complete the necessary tasks.
>
> Genuinely interesting task that appeals to all engineers.
>
> Good exercise in teamwork, (as complex task could not be accomplished by an individual in the time available).

Such positive comments were interspersed with more reflective views that nevertheless supported the overall activity design:

> Although had some initial student grumbles (because information had to be found), from quality and scope of information included in the final presentations, conclude that information searching was successful, and session worked.
>
> There is a lot to do in the Saturday evening session [but] recommend retain ambitious list of things to do … as it encourages all students to participate and engage with their group at an early stage.
>
> Student tended to oscillate between 'not enough information' or' too much' so learned to develop searching (keyword definition) strategies and to prioritise information.

Finally the role of the activity in context of the residential school as a whole was also mentioned:

> Very good ice-breaker [for students who have not met before] for both Activity A and the whole residential school.
>
> Because the whole activity forms a good project, it was nice and easy for tutors to do a final wash-up of both content and process (and relate these to learning outcomes).

Overall, tutor feedback was overwhelmingly positive and tutors were actively engaged not only in facilitating the activity but also in providing constructive feedback on its design and implementation.

Improvements made based on feedback

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 of the residential school. These improvements can be categorised into:

1. detail changes to the student activity notes to aid clarity
2. detail changes to the tutor activity notes to give clearer guidance
    - circuit board recycling
    - selection of products for dismantling
    - encouragement to students to review conference posters available on campus
3. changes to the timetable
    - allow more time for a plenary discussion in Session 3
4. additional equipment to support Sessions 1 and 3
    - sample bags for small components
    - a means of weighing heavy items

- materials for poster preparation.

Some further proposals were not implemented in 2011 but remain to be considered for future presentations:

1. digital camera [a USB digital microscope is already provided that can capture images]
2. additional information resources such as a glossary and a guide to plastics recycling.

Conclusions

This study paints a picture of a highly successful and innovative learning activity for Open University students attending a week-long residential school in engineering.

Feedback obtained from both students and part-time teaching staff through questionnaires and telephone interviews provides extensive support for the design and delivery of the activity in context. A variety of suggestions for ways in which the activity could be further refined and improved are provided in the feedback but none points to a need for major change.

Sufficient detail is given in this report and the supporting documents (available on request from the authors) for others to attempt to adopt the activity in their own programmes. Account must be taken of contextual factors, however, when analysing the success of the activity. The three activity sessions are dispersed through a single week of intense practical project work where students who are previously unknown to each other must work together in teams. The activity therefore performs several roles that transcend the learning associated with studying end-of-life product design. Whether this multiplicity of roles is a factor in the success of the activity can only be tested by transferring it to a different context and repeating the evaluation exercise.

To this end we should like to pose the following questions for other researchers to address:

> Does increasing or decreasing the timescale over which the activity is presented alter its effectiveness in any way?
>
> How portable is this activity to other HE providers with a different student demographic profile from The Open University students?
>
> What would happen if the students had access to more sophisticated workshop/materials and characterisation/presentation facilities?

References

Adams, A., Cox, A.L. (2008) *Questionnaires, in-depth interviews and focus groups*. In: Cairns, P & Cox, A.L. eds. *Research Methods for Human Computer Interaction.* Cambridge, UK: Cambridge University Press, pp. 17–34.

Adams, A., Lunt, P., & Cairns, P., (2008) *A qualitative approach to HCI research.* In: Cairns, P & Cox, A.L. eds. *Research Methods for Human Computer Interaction.* Cambridge, UK: Cambridge University Press, pp. 138–157.

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

Strauss, A., Corbin, J. (1990) *Basics of qualitative research: grounded theory procedures and techniques*, London: Sage Publications

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