MECHANICAL DISSECTION IN AN INTRODUCTORY ENGINEERING DESIGN MODULE

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ABSTRACT

The introductory design module for first year students in the Department of Mechanical Engineering at the University of Strathclyde uses mechanical dissection as a focus for learning activities that seek to integrate engineering science with the prior knowledge of the students. First year groups select and remove components from a scrap motor car, and produce a technical description of the system including consideration of function, mechanics, materials and manufacturing processes. Personal and professions skills and interpersonal skills are developed through enquiry based learning. This encourages the students to identify problems and engage in analysis requiring estimation and uncertainty; sourcing information in a critical manner to integrate in their description of the chosen component. Group and communication skills are developed through peer discussion and the presentation of their research in the form of a poster and formal seminar. Student feedback indicates a high level of enjoyment of, and engagement in many of the learning activities. However, focus group interviews and questionnaire responses indicate that the key area of metallurgy has proved to be difficult for many students, probably due to a lack of relevant background knowledge. Further development of the learning activities in metallurgy is planned, including pre-reading and peer instruction to prepare the students for the staff-led materials examination sessions. Continuing evaluation of the learning experiences of the students will be undertaken to assess the effectiveness of these developments.

KEYWORDS

Design, Mechanical Dissection, Introductory Course, PBL.

INTRODUCTION

The Department of Mechanical Engineering at the University of Strathclyde takes in approximately 160 new first year students each year. The department has invested considerable resources to enhance the first year experience in an effort to increase student engagement and establish a firm foundation for learning in later years of the programme. This effort has centred on two main activities: active learning in core engineering science classes, and hands-on problem and project based learning focussed on design. This paper describes one key element of the problem based design class, involving a major mechanical dissection activity.

At the start of the first year, students are formed into groups of four, and take part in a full day of induction activities to help them get to know each other, and to promote effective group working. For the whole year, students undertake a range of learning activities in these groups of four: they sit together in the active learning classroom, complete design activities as a group, and are tutored by the same academic counsellor.

A core component of the first year experience is the introductory class called Mechanical Engineering Design. The students work in groups on a range of teaching and learning activities, aimed at drawing together various aspects of the core engineering curriculum, and promoting links between engineering science disciplines. One large element of this module is Mechanical Dissection.

MECHANICAL DISSECTION

Background

Mechanical dissection is a teaching and learning activity involving the study and appreciation of a pre-existing artefact, usually including its disassembly, in order to discover how it works. It is an adaptation of reverse engineering, a technique used in industry, usually to gain understanding of a competitor's products for commercial advantage.

Mechanical dissection has been used as a focus for engineering education, notably at Stanford University [1], but has also been adopted in various forms in other schools [2-5]. Related approaches include more virtual studies of engineering systems, without a hands-on dissection experience [6].

In general, hands-on dissection activities have utilised small consumer items such as a computer printer, fishing reel, bicycle, corkscrew, door handle. The stated aims of the modules are along the lines of those listed by Sheppard [1], as follows:

> "1. to give mechanical engineering students an understanding of mechanical artefacts through hands-on dissection experiences and exposure to the vocabulary of mechanical systems,
>
> "2. to develop an awareness of Design Process through hands-on design exercises/assignments that highlight the importance of functional specifications in design and how they map into specific functions, and the non-unique mapping between functional specifications and the final design solution (*i.e.*, multiple solutions),
>
> "3. to make students aware of the power of clear, concise communications (oral, written and graphical) by having them present descriptions of mechanical artefacts and critique each others work,
>
> "4. to develop resourcefulness and problem solving skills through labs that require students to reason about function of three-dimensional objects."

The Strathclyde Dissection Class

The activities reported in this work centre around the dissection of a large engineering artefact, namely a complete motor car. Working in their groups of four, students select and remove a component or system from a scrap car. In this context, the component is something that performs a mechanical function. Examples of components examined include the braking system, steering, suspension, driveshaft, piston and connecting rod, valves, cooling system, alternator, fuel injection etc.

The component is disassembled and prepared for examination, and the students discuss their component in depth with a member of teaching staff. This informal discussion is the key activity in this module, providing the students with detailed information and a framework for further study. During the discussion, the group explores the function of their component, and the performance characteristics that are necessary for its effective operation. They attempt to quantify the relevant conditions of service which may include the forces, torques, friction conditions, temperatures, stresses etc. This will probably include calculations based on estimated quantities, under the guidance of the instructor. The aim here is to show the relevance to the design process of material taught in the first year engineering science classes, as well as prior knowledge that students bring from their pre-university studies.

Part of the discussion involves selection of parts of the component to be sectioned for materials examination. Specimens are prepared for microstructure examination, which is carried out by the group and an instructor approximately one week after the initial dissection lab. During this second session, the materials from which the component parts are made, together with the manufacturing processes used are explored. The students are provided with a set of notes and photographs of the microstructures.

The group spends approximately three weeks researching background information and preparing a poster to summarise their findings. The poster is presented to the course leader, who provides detailed feedback to the group about the accuracy and appropriateness of the poster contents. At this stage, any further work that is required to bring the poster up to the required standard is specified and explained in detail. The group completes this work over the next three weeks. At the end of this period they deliver a short seminar presentation to a selection of other student groups. This allows them to share what they have discovered with other students, and gives them an experience of presenting technical information to an audience of their peers. The seminar also provides an opportunity to mark the completion of this significant activity in the first year of their course.

CDIO Skills

The intended learning outcomes of the module include the development of attributes and skills that are characterised in sections 2 and 3 of the CDIO syllabus: namely personal and professions skills and interpersonal skills [7].

In particular, students are exposed to problem identification and formulation, estimation and qualitative analysis and analysis with uncertainly. They need to analyse their component, often with incomplete information, using realistic estimated quantities. They are required to carry out research, which develops the ability to survey printed and electronic literature. This is an important element in that it encourages students to think critically about sources of information.

Systems thinking is developed by the students being encouraged to see the mechanical design, materials selection and manufacturing processes as interrelated topics. Personal skills and attitudes are fostered, particularly time management and an awareness of personal knowledge and skills.

Working in groups helps develop interpersonal skills related to team working and communication. Formal and informal modes of communication, both written and verbal, are utilised in the module. Feedback is given to students on the effectiveness with which they have achieved this.

EVALUATION OF LEARNING OUTCOMES

Evaluation of the effectiveness of the class has taken two main forms. General feedback from students is possible because of the small group nature of the activity. The students enjoy the activity, and frequently research their chosen component in great depth. They become familiar with the need to find things out for themselves, and be critical concerning information that they retrieve. Independent evaluation has been obtained through participation in the UK Higher Education Academy Engineering Subject Centre Teaching Award scheme. This evaluation initially confirmed the general effectiveness of the approach to the teaching of design [8].

Focus Groups and Questionnaire

Recent evaluation work has utilised structured focus group interviews. Student groups were asked a series of questions to discover their attitudes towards and enjoyment of various aspects of the class. [9] They were also questioned about the sources of information they had accessed during the research phase of the project, and asked to reflect on what they had learned about various topics.

Students reported a high level of enjoyment for the practical aspects of the dissection activity, claiming to have learned a lot from this process, and the grounding of the mechanics aspects in a concrete setting. Questionnaire responses indicated that students consider the initial discussion with staff is important to the learning process, although opinion is evenly divided about their enjoyment of this part. Learning about the function and design of their chosen component was seen as enjoyable and effective in promoting student learning.

Students are less comfortable giving verbal presentations, but generally acknowledge that while they did not find this aspect particularly enjoyable, they have learned something through being required to do it.

One strong theme in the interview responses was that students reported a difficulty in engaging with the subject of metallurgy. The students admitted to a lack of background knowledge in this field, in contrast to generally high levels of knowledge and familiarity with concepts in mechanics. A typical comment about this topic was:

> “Metallurgy: lots of information given and terms used which we did not understand”

This lack of ‘appropriate background knowledge’ is likely to be detrimental to employing a deep approach to learning [10]. It is clear that some alterations to the teaching and learning activities in this area would be desirable to enhance the students’ learning experience. The depth of learning in the area of metallurgy is somewhat variable, with some students delving deep into the subject, accessing a wide variety of resources, while the remainder skim over the surface and learn very little.

To address this issue, activities are under development to improve the constructive alignment of this element of the course. A more student-centred approach to the learning related to materials will be implemented, including directed private study/pre-reading and peer instruction. A range of briefing materials have been produced covering the materials and manufacturing aspects of the dissection project. During the initial informal discussion with staff, the students will each be given pre-reading task on one small topic in materials, chosen to be relevant to the component they are studying. At the next meeting, in a staff-facilitated seminar, students will brief each other on their research topic, prior to the staff-led metallography session. The students will be asked to formulate questions to be investigated using the knowledge gained in examining the structure of their component: these are likely to relate to material structure and properties as well as processing methods.

Further evaluation of the learning experiences of the students will be carried out concurrently to assess the effectiveness of this approach.

CONCLUSION

The mechanical dissection module has proved to be popular and enjoyable for first year students, and the learning outcomes in terms of the integration of various aspects of the engineering science curriculum with prior knowledge are generally fulfilled well. Evaluation of the class by focussed group interviews and in class questionnaires has highlighted the difficulties many students find in engaging with the subject of metallurgy. Lack of prior background knowledge in this area may be encouraging a more surface learning approach. Modifications to the learning activities in this area are planned, to include pre-reading, peer instruction and student-led question formation as a pre-curser to the practical metallography session. Continued monitoring of the student learning experience will seek to evaluate the effectiveness of these measures.

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Biographical Information

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