AC 2008-980: RESEARCH SKILLS IN A MECHANICAL ENGINEERING CURRICULUM

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Research Skills in a Mechanical Engineering Curriculum

Introduction

All teaching and learning in a university is rooted in research[1]. On the one hand that is so, because learning to become a researcher is a core objective of University training. However, there are also pedagogic arguments. The understanding of scientific method helps the students to develop a generic approach to problem situations. Students who are exposed to research during their graduate years will be encouraged to develop a questioning and inquiring mind and will be less likely to accept uncritically and passively the "truth" as propounded and handed down in the lecture books and by the professional expert[2]. Several publications on undergraduate research in technology education suggest that research enhances student learning, increases retention, increases enrolment, stimulates critical thinking and directs the students towards a richer innovative culture[3;4;5].

In most European engineering curricula, however, learning how to conduct research is reserved for the more advanced students. In the Bologna declaration the European countries agreed to implement a Bachelor-Master structure (3+2 years) as a unifying structure for higher education in Europe. During the first three years of the Bachelor program students focus on fundamental knowledge and basic skills. Students with a bachelor degree can opt for a variety of Master programmes inside or outside their own institution. Usually, the Master programmes are closely linked to a research group. As a consequence, most students get the first opportunity to familiarize themselves with scientific research during the Masters phase[6].

In the Netherlands, the introduction of the Bachelor-Master structure did not result in extensive curriculum change. The typical engineering curriculum consisted of 5-year programmes, with intermediate exams after one year and at the end of the third year. Accommodating to the Bologna criteria basically came down to an upgrade of the status of the third year examination. At the Faculty of Mechanical, Marine and Materials Engineering (3ME) of Delft University of Technology it was decided the training of research skills should be part of the bachelor program. Since over a decade, the last course before the third year examination takes the shape of a research project. In the present curriculum this project is labelled the “Bachelor Project”. This paper presents an outline of this course based on experiences of the last ten years.

Outline of the bachelor project

There are some marked differences between engineering and research. The primary purpose of research is to explain the phenomena we observe in the world. Engineering aims to exercise control over those phenomena and to change the world through innovative technology. Still, university trained engineers need to understand scientific methods in order to produce effective designs[7]. The learning goals of the BSc research project are: to stimulate an engineering research attitude and to master basic skills to perform some (small scale) research. The basis format of the course is that of a project where the students are responsible for planning their own research. A team of staff members supports their efforts, including two staff members from the faculty of Technology Policy and Management (TPM) who provide expertise on research methodology.

During a semester small groups of students (2-4) have to work on a research assignment. At the start of the project the students have to indicate their preference for the available

assignments, drawn up by the staff. The groups are assembled, based on their choice of topic. In the opening session each group is handed out a project brief containing a description of a research topic including a research question phrased in general terms (see the next section for a few examples). Students can start with the BSc project only if they passed successfully all other projects of the first three years. Only a few minor deficiencies in the second year and the third year are allowed. Each year the BSc research projects runs two times: once from the beginning of the academic year until Christmas and the second one from Christmas until the end of the academic year. The students are supposed to spend approximately 240 hours of work each on their project, equalling 9 EC (in the European Credit point Transfer System a full curriculum year consist of 60 EC).

Each group has a staff member assigned as a supervisor who they can consult and to whom they report on a weekly basis. However, the students are responsible for the planning of their own project work. During the course of the project the students are supported through a series of lectures and feedback sessions. About ever other week the students are expected to attend a plenary session. The timetable of the course contains 5 lectures and 4 feedback sessions. The lectures presented by the TPM staff members introduce some basic concepts of research methodology, just at about the time that the students are face with the respective issues[8].

In the first lecture students are explained basic paradigms of scientific research. The importance of (re-)formulating your own research question is stressed. The second lecture explains the principles of research design and the importance of aligning the methods of date gathering to the type of research question. The third lecture explains measurement scales. This is necessary, mainly because the students appear to assume that all measures are metric. The explanation on different types of measurement scales sets the stage for a user oriented explanation on statistics. Finally at the end a lecture on logic and reasoning helps to prepare the students for the writing of their reports.

In between the lectures feedback sessions are planned. In these sessions each group gets a turn in presenting their work to the others. Staff members comment on the students' work, both from the methodological perspective as well as from the engineering point of view. In the first feedback session the groups have to present the hypothesis they want to investigate, next their research design, their method of data processing, etc. The feedback sessions are supposed to contribute to the development of a critical scientific attitude. First the staff members take the lead, but later on students start questioning each other's research plans. Every group member has to participate in giving the responses. The last feedback session is a trial for the final presentation.

The assessment of the student's achievements consists of several elements, covering both individual and group performance indicators. The groups have to produce an extended abstract (2 A4 sheets), a poster (A0) and a logbook detailing the work they have done. Mastery of the relevant knowledge on research methodology is tested by means of a paper-and–pencil test, a week before the end of the project. And finally the groups have to present their work on a mini-symposium supported by Power Point slides. The poster used to be judged also. However, this dropped because it appeared to be redundant. Yet the poster was left as a product to be produced, because the exercise of making a poster was considered to be useful. Rating the posters was left to the audience, resulting in a competition for the best poster award.

The mini symposium plays a central part in the assessment strategy of the project. The students have to present their research in 20 about minutes to the assembled fellow students, parents and staff members. Each presentation is followed by questions and discussion with the audience. A jury of four experienced researchers judges the performance, resulting in a group mark. In the jury deliberations individual performance during the presentation and discussion is weighed and counted as plus or minus in relation to the group mark. Plusses or minuses are also assigned by means of the paper-and pencil test and by the report from the supervisor (supported by the logbook entries). At the end the jury decides on an individual final mark.

Project assignments

All staff members of the Faculty of Mechanical, Marine and Materials Engineering are invited to submit assignments for the BSc research project. In many cases, these assignments are part of ongoing research, a side step, or an aspect that could merit some extra attention. The project assignments are composed like a research question from a contractor who hires a small engineering firm to answer a practical question. Just like in real practice the teams have to work hard in the beginning in order to translate the practice-oriented question into a research question. In the context of engineering design the contractor very often is not so much interested in the scientific thoroughness of the research. They simply want to know if a particular procedure or material fulfils the requested demands. Many groups tend to fall into the trap of turning such a client wishes directly into their research question, ending up with a hypothesis of the type: does it work or not? See below for an example of a typical project assignment.

Table 2.: Example of a project assignment

Title	Instruction for driving in a simulator
Keywords	Car simulator, instructions, driving skills, feedback, training
Introduction	TU Delft works together with the company Green Dino Virtual Realities in the development of the Dutch Driving Simulator. This is a cheap and easy simulator, which is by now used at about 90 driving schools. The simulator operates with virtual instructors. However, these instructions are not completely in line with general recommendations in the literature. Based on previous research a new set of instructions is drawn up. In order to find out the difference in effectiveness of these new set of instructions, a comparison with the old ones will have to be made. Also the research should provide evidence regarding the effectiveness of the newly implemented movements of the driver's chair.
Research questions	1. Do people learn faster how to drive away with the new instruction? 2. Do people learn faster how to drive away when extra feedback is given in the form of movements of the driver's chair?
Specifications	It is expected that o the present procedure of driving away will be analysed o a new lesson for driving away will be implemented on the simulator o hypotheses will be formulated o an experiment will be carried out in the simulator

Experiences with the bachelor project

During the academic year 2007-2008 the bachelor project has been running for the 16th and 17th times. A clear indication of the success of the project is that the basic set up has remained unchanged during this time. The involvement in the project is generally good. Running the project is demanding on the staff. In particular the feedback sessions can be exhausting. The reward is to see the students growing each time again. At the beginning of the project most of them are rather shy and they feel comments almost as a personal attack. Already halfway through, the students have learned to be critical on themselves as well as towards their colleagues. The evaluation of the course by the students is mostly positive. That means the most important objective of the course is realized[7].

One factor that gave rise to some logistic adjustments was the increase in the number of participating students, from about 25 the first time to 70-80 students per run in recent years. Because of this the group size was raised from originally two students to a group of four. Also the feedback sessions became unwieldy, so that it was decided to work with subgroups of about 25 students at a maximum. Only with the lectures all students are to be present at the same time. Running the project has become more complicated, but the essential learning experience of being involved in engineering research stays intact. Therefore we may conclude that the BSc research project is a successful course in the curriculum of the Faculty of Mechanical, Marine and Materials Engineering.

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