SPECIALIZED BASIC COURSES FOR ENGINEERING STUDENTS: A NECESSITY OR A NUISANCE?

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Basic statistics courses for engineering students often focus on general applications in engineering, using course literature intended for 'engineers'. However, these students are not a homogeneous group, and the differences among engineering programmes appear to be increasing. One way to meet the challenge of the diversity of needs within a discipline is to adapt the courses for different programmes. This could also be a way of increasing students' motivation. During the past decade, several of the statistics courses given at the Faculty of Engineering at Lund University have been specialized with regard to syllabi, applications and teaching methods. We discuss the factors involved in specialized course development, as well as the challenging implications for the teachers and department involved.

BACKGROUND/INTRODUCTION

Statistics education for engineers faces many challenges. One of the greatest is motivating the students and making them understand that statistical concepts and methods are useful, not only to pass their exams, but in their future profession as engineers. Several authors have described the problem. See, for example, Romeu (2006) and Petocz and Reid (2005).

One way to increase students' motivation may be to make the course more relevant to their profession by using suitable data and engineering context. However, the use of literature for "general engineers" together with general applications chosen from engineering practice appears to be inadequate. Engineering students are not a homogeneous group, and during the past decade we have noticed an increasing heterogeneity among these students, indicating that perhaps they should not be given the same basic statistics course, but that different courses should be developed for different engineering programmes.

At some universities there is no choice: the policy is to give one basic course in statistics/mathematical statistics for all engineering students, often for economic reasons. Providing courses adapted to the needs of different fields of engineering requires both financial resources and the motivation of the staff involved.

At the Faculty of Engineering at Lund University, six basic courses in mathematical statistics are available to students in 16 engineering programmes. Several of these courses are specialized to varying degrees for different fields of engineering. In this article, we give examples of this, and discuss the implications for the teachers and the department.

WHY SPECIALIZED COURSES?

The methods used by mathematics and statistics lectures to engage an increasingly diverse student body vary (see, for example, Henderson & Broadbridge, 2007). Some of the factors we have found to promote the development of specialized basic courses in mathematical statistics at Lund University, are discussed below.

There are differences regarding the statistical knowledge that will be required in the engineer's future profession. Some engineering students take only a basic course, and will use statistics little, while others will have a greater need of statistics and probability in their future profession, and therefore take more advanced courses.

There are also differences among programmes in the students' experience of variability and thus attitudes towards the usefulness of statistics (Lindgren & Zetterqvist, 2006).

New engineering programmes are constantly being introduced, often involving combinations of less traditional engineering subjects. Fresh views on the role of traditional subjects such as mathematics and statistics, and different teaching methods tend to widen the gap between programmes.

There also seems to be a tendency for students in a certain programme to have a wider range of abilities. If it is accepted that motivated students perform better than unmotivated ones, connections to our students' professional and personal lives become even more important.

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Furthermore, there may be differences among the policies of the programme boards concerning, for example, demands on the statistics course, software availability and pedagogical methods. During certain periods, these separate boards have been economically responsible for purchasing courses in statistics.

The Faculty of Engineering at Lund University has a clear policy concerning education, and there is lively discussion on pedagogical issues among teachers. Education at all levels in the Faculty is characterized by teaching and supervision at a high academic level, by staff actively involved in research. There is a high degree of student involvement, strong emphasis is placed on student-centred pedagogic development, and there is an open and democratic atmosphere with an informal relationship between staff and students.

COURSES IN BASIC STATISTICS AT THE FACULTY OF ENGINEERING

The Faculty of Engineering at Lund University has 16 engineering programmes with about 1500 students enrolled each year. A basic course in mathematical statistics is compulsory for all but two of these programmes. Students in six of the programmes take an extended course laying the foundation for future studies in processes. Students in the remaining eight programmes take a somewhat shorter compulsory “service course’’ with the following aim (from the syllabus for the course FMS140 at LTH, academic year 2009/2010):

> The course fills two purposes: providing fundamental knowledge in mathematical statistics, as well as the foundation for further studies. This fundamental knowledge is essential for those who, in their professional lives, will not necessarily be involved in statistical analyses on a daily basis, but who, on occasion, will be expected to perform basic statistical tests and present the results to their colleagues. They will also be expected to be able to read and assess the analyses of others.

To exemplify the idea of specialized courses, we present three courses for engineering students on different programmes. After having studied maths courses in calculus and algebra, the students take this course in the 2nd or 3rd year of their university studies. The course runs half-time for seven weeks, and students typically take one other course in parallel. The specialized courses for five fields of engineering are summarized in Table 1.

Table 1. Summary of three basic courses in statistics adapted for five engineering programmes at Lund University

	CHEMICAL ENGINEERING, BIOTECHNOLOGY	ENVIRONMENTAL ENGINEERING	CIVIL ENGINEERING AND SURVEYING
Number of students on the course	120	60	160
Stage in the studies	5th semester	5th semester	4th and 3rd semesters respectively
Syllabus	Basic + Experimental design	Basic + Time series	Basic + Extra distributions
Teaching method	Traditional + Project	Cooperative learning + Project	Traditional + Consulting cases
Number of lectures and tutorials per week (7 weeks total)	4 h lectures 6 h tutorials	2 h lectures 8 h tutorials	4 h lectures 6 h tutorials
Assessment	Written examination + Project	Written examination + Peer-reviewed project + Self-reviewed assignments	Written examination + Peer-reviewed reports of consulting cases
History of course	Started in 1964; internal course for the Chemical Dept in the 1980s.	New course when the programme started in 2000.	Started in 1964.

HOW ARE THE COURSES SPECIALIZED?

Two main approaches are used to guide our work when developing specialized courses. Regarding the aim of the course, we have focused on what the student should be able to do. The concept of “Capability-driven curriculum design” was introduced by Bowden (2004). The second approach used is “Constructive alignment” (Biggs & Tang, 2007), where the aim is to align the learning outcome, the learning and teaching activities, and the method of assessment.

Syllabi: All engineering students need a basis in statistical concepts. The basic concepts include elementary probability, standard distributions, the central limit theorem, estimators, confidence intervals, hypothesis tests and linear regression (simple and multivariate). In addition to this, we have included topics we deem to be useful in specific programmes. Examples of such topics are the elementary design of experiments (Chemical Engineering), introduction to time series (Environmental Engineering), least-squares estimation (Surveying) and distributions for fatigue and extremes (Civil Engineering). These extra elements are chosen in collaboration with representatives/lecturers/programme coordinators from the respective programme.

Literature: The choice of literature depends on various factors, such as the suitability of the examples in the literature, the mathematical level, and its conformity with the teaching method employed. The literature for chemical engineers and biotechnology, for example, was chosen because it was developed specifically for industrial and chemical engineers. The courses given to students on the other programmes use the same basic literature suitable for the teaching method used (cooperative learning) and including the basic concepts with extra material for the programme in question supplied by the lecturer.

Applications: One of the most significant consequences of providing specialized courses is the focus on applications. After several years of development, almost all the examples given in lectures, exercises, computer exercises and in the exams are applications specific to each programme. These can be developed in various ways. One way is to make use of other courses in the programme. For example, civil engineering students analyse data on the speed of vehicles, collected by the students themselves in their course on traffic planning. Other sources of applications are Master's dissertations, consulting activities or research at our department. Applied journals, course literature, databases (e.g., environmental databases) and material from the mass media are other examples of sources of interesting material for the courses. However, when an interesting example is found, we still face the intriguing question of how to use it in the course. This is discussed later in this article.

Teaching methods and assessment: To some extent, we have developed different teaching methods (and methods of assessment) for the different courses. Available resources, the number of students in the course and the students’ experience of variability are examples of factors influencing the choice. However, tradition at the department, the expectations of the engineering programme board and the culture of the programme also affect the course. These so-called “soft” factors are examples of Teaching and Learning Regimes (TLR), which were introduced by Trowler & Cooper (2002). For example, the courses in mathematical statistics at our department have a long tradition based on mathematics courses: lectures, exercises with pen and paper, and a written individual exam. With the advent of new technology we introduced computer exercises, but in most cases the teaching method and assessment remained the same.

The history of the course for chemical engineers is interesting since it illustrates different factors that resulted in a specialized course. In the late 1980s it was a very traditional course: there was no data analysis using computers, and the literature was the same as for our course for statistics majors, although a shortened version was used. There were few examples of chemical applications, and those that were used seemed contrived. Students found the course theoretical and boring. As a result, the Chemical Engineering programme board decided to develop a statistics course of their own, using data and methods useful for chemical applications. The result was a course with advanced methods but no firm basis in fundamental statistical concepts. The students found this internal course very difficult. After a couple of years, the programme board decided to extend the statistics course, and our department was engaged again, on the condition that we developed a specialized course. Several factors contributed to the success of this action. An external statistics course developed at our department for a large food technology company had resulted in extremely suitable literature for chemical engineers. At the same time, support from the Swedish Council for the Renewal of Undergraduate Education gave us the opportunity to develop applied exercises/projects for the extended course. Finally, researchers and teachers at the Department of Chemistry willingly helped us through discussions, and by supplying background descriptions of the exercises/projects, as well as data. The resulting course has been described by Zetterqvist (1997).

The experiences gained from this process was useful when the new programme in Environmental Engineering was introduced in 2000. As this was a completely new programme involving less traditional engineering subjects, it was not weighed down by tradition. The programme board had also adopted a policy of using a mixture of pedagogical methods. Each student was given a laptop at the beginning of their studies, and when taking our course the students already had experience with variability in environmental measurements. This made it possible to develop a statistics course with environmental applications. The course was characterized by frequent use of computers in tutorials and examinatons, peer-reviewed projects and good exam results. After a few years, cooperative learning was introduced into our statistics course together with an advanced course in calculus. The main reason was to help weaker students in the maths course. The statistics course for Environmental Engineers is described by Lindgren & Zetterqvist (2006) and Zetterqvist (2007).

The situation is quite different for the traditional programmes in Civil Engineering and Surveying. The approach of cooperative learning, which has been successful in Environmental Engineering, is not realistic due to a lack of resources, mainly a lack of experienced teachers. The number of students is large, and lectures are complemented with exercises, often led by senior students. When taking our course during their second year of studies, the students have less experience with variability as they have not yet taken experimental courses. The greatest problem has been motivating students and changing their attitudes to the subject. Although they encounter many applications in lectures and exercises, many of them do not seem to see the connection to their future profession. Therefore, we have introduced role play in the form of small consulting cases to increase students' motivation and change their attitude. Students are presented with a small engineering problem of the kind facing civil engineers and surveyors. The scenario is that the students are newly employed at a consulting company, and have been asked by a senior employee to perform a statistical analysis as part of a larger consulting project. They solve the problem using computers and write a report, which is presented to, and discussed by, their fellow students who play the role of senior employees. After this peer review, the report is handed in to the teacher for assessment. During the course, the students are thus actively working in two realistic engineering situations and reviewing/discussing two others. This project will be evaluated in the spring of 2010.

IMPLICATIONS FOR STUDENTS' LEARNING OUTCOMES

What effects have these specialized courses had on students' learning outcomes? We have devoted a great deal of time and effort to changing students' attitudes to statistics. Naturally, both students and teachers of the engineering programmes highly appreciate the use of relevant applications in the statistics course.

For all compulsory courses at the Faculty of Engineering, students are asked to evaluate the importance of the course in their education. A standardized course evaluation form is used for this. In our experience, the more specialized a statistics course is, the higher the students rate its importance. Furthermore, the examination results are often better for more specialized courses, but it is difficult to determine whether this is an effect of specialization of the course. However, motivation is related to performance and the quality of learning (Biggs & Tang, 2007). Motivated students are more inclined to deep learning than surface learning. An unpublished investigation suggests that weaker students became more active, and their results improved when cooperative learning was introduced into the statistics course for environmental engineers.

IMPLICATIONS FOR THE TEACHER AND THE DEPARTMENT

What does this mean for the teacher and the department? Below we discuss several factors that we have found to be important.

Developing specialized statistics courses inevitably requires discussions between lecturers in statistics and the board and lecturers of the programme in question, concerning the syllabus and applications. These discussions often create a positive attitude to statistics as useful and flexible, working towards unified education of the student. It is sometimes necessary to strike a balance, as users often wish students to work with advanced statistical methods without having the necessary basic knowledge (compare the example of chemical engineers). As described by Lindgren & Zetterqvist (2006), collaboration often facilitates the evolution of a shared view of the role of statistics in the programme.

Finding suitable examples/projects is difficult for several reasons. The statistical problem should not be overwhelmed by the engineering problem. If the basic statistics course is given too early in the programme, the students will not have sufficient knowledge in engineering. One solution is to use a combination of real engineering problems, adapted engineering problems and statistical problems based on interesting (but not engineering) data/situations. As discussed above, we have taken examples from various sources, including course literature, applied journals, databases, Master's dissertations, consulting activities and research at our department.

However, an interesting and suitable application does not guarantee pedagogical success. There is still the problem of implementation. It is not sufficient to present a relevant engineering example in a lecture and assume that all the students will find it an interesting application for statistics. Even a short exercise will for some students pass as "just another maths problem, dressed in a fancy but uninteresting wrapping", and they will fail to see the intended connection. Several statistics teachers have found that students have to work actively with the problem by themselves to become engaged. The greatest engagement is achieved when data have been collected by the students themselves, or if the students see a clear connection to a future working situation. For this reason, we have worked actively to make use of measurements from courses being studied in parallel, small but adequate consulting cases and projects with work-like situations. If several groups of students are being taught the course, it may be necessary to give them different exercises and projects.

When developing suitable teaching methods for statistics in an engineering programme, and working to change attitudes, Teaching and Learning Regimes must be considered at the programme level. In other words, it is necessary to "identify the culture" of the programme regarding pedagogical policy (if one exists) and suitable teaching methods, and try to adopt a unified view of the curriculum. It may also include the intriguing aspects of observing attitudes to statistics among teachers and students.

There are several challenging implications on the departmental level. Consensus among the teachers within the department to work towards specialized courses is desirable. Even if the statistics lecturer does not have full knowledge of the engineering application, he/she must be curious about applications in the specific programme. An open mind to different teaching methods, as well as to pedagogical discussions, is also important.

Implementing specialized courses could be affected by changes in the staff at the department, since a statistics teacher often develops a personal relationship with teachers in the programme during the discussion of the course. It is thus important that a course is the "public property" of the department, and not the "pet project" of one single teacher. Establishing a team of teachers responsible for similar courses could be one solution to the problem.

The most crucial issue is naturally that of resources. Developing specialized courses involves a considerable initial cost, for example, costs associated with updating course material, and re-training teaching assistants in different teaching methods and different exercises/applications. One solution is to use basic material together with a basic teaching method, supplemented with "extras". In our case, we had initial support from the Swedish Council for the Renewal of Undergraduate Education.

In financial discussions with the programme boards, offering specialized courses can be used as an argument for including the course, and a positive attitude towards the subject as being useful and flexible is often created. On the other hand, when a faculty or university is under pressure, as in times of financial crisis, specialized courses are one of the first targets, often being replaced with a general, "one-size-fits-all" course. A good relation with the different programme boards and a common view on the role of statistics courses are then essential.

CONCLUSIONS

We have found specialized courses to be necessary when teaching basic statistics courses to engineering students. Increased motivation and hopefully a higher quality of the learning are the main reasons. Collaboration between departments creates a positive attitude amongst teachers and programme boards and may open the door for future communication.

Several factors must be considered when designing specialized courses. It is not trivial to find and implement interesting and relevant examples/applications. Following the approach of Constructive alignment, it is also necessary to devote attention to the methods of teaching and assessment of the course. The "culture" of the programme, as well as the attitudes and abilities of the students must also be considered.

Consensus among the teachers in the department to work towards specialized courses is desirable. A team of teachers responsible for similar courses could ensure the continuity of the courses. Sharing experiences and ideas from other courses and reusing material could reduce the initial cost of course development.

REFERENCES

Biggs, J., & Tang, C. (2007). *Teaching for Quality Learning at the University: What the Student Does.* Maidenhead, New York, NY: McGraw-Hill/Society for Research into Higher Education: Open University Press.

Bowden, J. (2004). Capabilities-driven Curriculum Design. In C. Baillie & I. Moore (Eds), *Effective Learning and Teaching in Engineering* (pp. 36-47). London: RoutledgeFalmer.

Henderson, S., & Broadbridge, P. (2007). Mathematics for 21st Century Engineering Students. *Proceedings of AaeE Conference.* Online: www.cs.mu.oz.au/aaee2007/papers/inv_Hend.pdf.

Lindgren, G., & Zetterqvist, L. (2006). Teaching Modern Engineering Statistics: The Contribution of Collaboration and Shared Views of the roles of Mathematical Statistics in Engineering. *Proceedings of ICOTS-7. Online:* www.ime.usp.br/~abe/ICOTS7/Proceedings/PDFs/Invited Papers/4A3_LIND.pdf.

Petocz, P., & Reid, A. (2005). Something Strange and Useless: Service Students' Conceptions of Statistics, Learning Statistics and Using Statistics in their Future Profession. *International Journal of Mathematical Education in Science and Technology, 36*(7), 789-800.

Romeu, J. L. (2006). Teaching Engineering Statistics to Practicing Engineers. *Proceedings from ICOTS-7.* Online: www.stat.auckland.ac.nz/~iase/publications/17/4A1_ROME.pdf.

Syllabus for course FMS140 at LTH, academic year 2009/2010. Online: *www.ka.lth.se/kursplaner/09_10%20eng/FMS140.html*.

Trowler, P., & Cooper, A. (2002). Teaching and Learning Regimes. Implicit Theories and Recurrent Practices in the Enhancement of Teaching and Learning Through Educational Development Programmes. *Higher Education Research & Development, 21*(3), 221-240.

Zetterqvist, L. (1997). Statistics for Chemistry Students: How to Make a Statistics Course Useful by Focusing on Applications. *Journal of Statistics Education, 5*(1). Online: www.amstat.org/publications/jse/v5n1/zetterqvist.html.

Zetterqvist, L. (2007). An Example of Assessment Being an Integral Part of a Service Course. *Proceedings of IASE/ISI Satellite.* Online: www.stat.auckland.ac.nz/~iase/publications/sat07/ Zetterqvist.pdf