THE MATHEMATICS EDUCATION FOR THE ENGINEERING STUDENTS OF 21ST CENTURY

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Abstract: Engineering is one of the most important professions for the mathematics discipline. New developments in engineering have stimulated new areas of mathematical research. Control theory, signal processing and coding theory are all examples for this. When taking into account the close relationship between engineering and mathematics, we can easily say that mathematics have a vital role in the engineering education. In the last twenty years, both new demands of the engineering profession and inadequate mathematics ability of the engineering students have led in a big change in the scope of the mathematics education. The recent developments in technology and computers have caused variation in teaching mathematics of engineering students and have brought with them the use of modern techniques and methods. This research aims to shed some light on how the mathematics education, which is an important part of the engineering education for the 21st century engineers, must be, by investigating the curriculum, teaching and measurement–assessment methods.

Introduction

The ever more rapid pace of technological development has created a situation in which many engineers will require frequent updating in areas of their specialization. This may involve the mastery of new techniques and understanding of new theoretical concepts. A fluency with mathematics is an essential weapon in modern graduate engineer's armoury (Mustoe& Lowson, 2002, p.3).

In the last twenty years, both new demands of the engineering profession and inadequate mathematics ability of the engineering students have led in a big change in the scope of the mathematics education. . The recent developments in technology and computers have caused variation in teaching mathematics of engineering students and have brought with them the use of modern techniques and methods.

Insufficient skills in basic mathematics cause problems for those majoring in engineering at university level. A big portion of students seems to be able to find correct solution to test and exam questions using familiar steps and procedures. Yet they lack deep conceptual understanding of the underlying theorems and sometimes have misconceptions (Norbert & Klymchuk, 2002). The one of the most important skills required of engineering students are problem solving and creative thinking, but they have some difficulties in these issues (Adams at al, 2007). In addition, the student profile has been changed and the number of international students has been increased. Almost all branches of engineering profession, in parallel with changes in technology, new demands arise.

Developments in educational technology, engineering profession's profile and the expected new demands on students' math capabilities and profile differences have effected mathematics education of engineering students.

In this study, changes in mathematics education for engineers are discussed in terms of curriculum, teaching and assessment methods.

Method

Survey method was used at this research of which aim is to discuss the changes that is happening in the mathematics teaching for 21th century engineers. Survey method is a research approach to describe a past or present situation in the way as it is.

Findings

1. Curriculum

The importance of a serious mathematics education for engineering was highlighted in many studies. While there is no consensus on the amount and content of the mathematics for different engineering disciplines, there is a consensus on the need for a basic mathematics in all of them (Broadbridge& Hendersen, 2008). The most effective subjects for engineering mathematics must be a part of an engineering program which must give the chance to see the main developments in the concepts and understanding for related subjects. The way mathematics is included in different engineering educational institutions curricula varies, but there are some basic requirements to be fulfilled (Mustoe& Lowson, 2002, p.2).

Mathematics Working Group of The European Society for Engineering Education (SEFİ) conducted an extensive study on the content of engineering mathematics at 2002. At that study a core program was developed which has four levels. These levels represent an attempt to reflect the hierarchical structure of mathematics and the way in which mathematics can be linked to real applications of ever-greater sophistication as the student progress through the engineering degree program (Mustoe& Lowson, 2002, p.8). The diagram of the core program is shown in Figure 1.

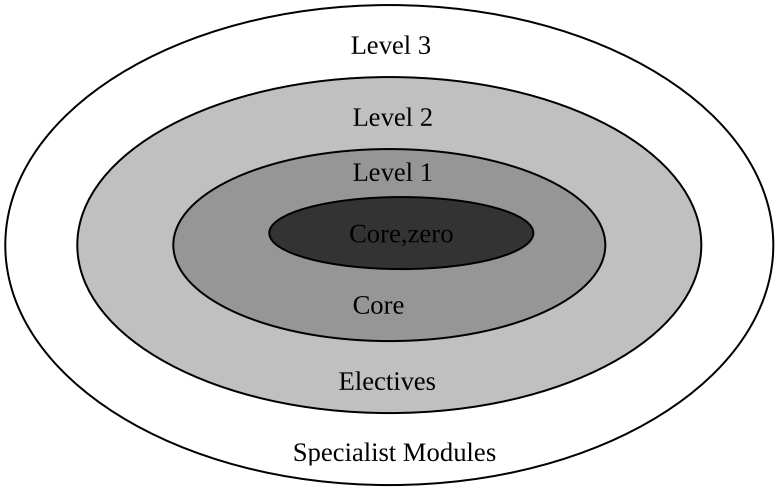

Figure 1. The schematic diagram of the proposed structure

Within the three main levels the material has been arranged under five sub-headings: Analysis and calculus, discrete mathematics, geometry, linear algebra, statistics and probability.

The core zero consists of the material that the freshman should study before entry to an undergraduate engineering degree program. The core zero contains material which together forms a solid platform on which build a study of engineering mathematics at university. The material in Core Zero has been grouped into five areas: Algebra, Analysis & Calculus, Discrete Mathematics, Geometry & Trigonometry, and Statistics & Probability (Mustoe& Lowson, 2002, p.11).

The material at core level 1 builds on core zero and is regarded as basic to all engineering disciplines in that it provides the fundamental understanding of many mathematical principles. The material in core level 1 can be used by engineers in understanding and the development of theory and in the sensible selection of tools for analysis of engineering problems. This material will be taught in the early stages of a university programme (Mustoe& Lowson, 2002, p.21).

The material at level 2 builds on core level 1. The material is advanced enough for simple real engineering problems to be addressed. Different disciplines will select different topics from the material of level 2 (p.32).

Level 3 is the one at which the mathematical techniques covered should be applied to a range of problems encountered in industry by practicing engineers. These advanced methods build on the foundations laid by levels 1 and 2 of the curriculum. It is quite possible that much of this material will be taught not within the context of dedicated mathematical units but as part of units on the engineering topics to which they directly apply (p.45).

2. The Methods of Teaching and Assessment

Lopez (2007) found a large body of research highlighting the need for educators of engineers to adapt to changing nature of both the engineering profession and the student population in the 21st Century. A more diversified student population requires a more comprehensive learning support system. Therefore, there is much debate as to how these changes should be addressed (Broadbridge& Hendersen, 2008, p.10).

Some problems which engineering institutions faced are listed below:

- a decline in the mathematical ability of entering engineering students,
- the lowering of entry standards and increased number of international students (it has also led to the increased diversity of students' mathematical backgrounds),
- the reduction of mathematical content and course hours,
- to cater mathematical needs for all engineering disciplines in one subject and the difficulty of reaching a shared understanding between the mathematics and engineering departments about what is to be included in the curriculum,
- the difficulty of teaching large classes with inadequate facilities,
- the lack of mathematics staff.

To resolve these problems, institutions and educationalists have begun to use new methods. Some examples of these are problem/project based learning, support programs for the students, online support, visual sources, mathematical software programs, online instructional materials, computer-aided assessment, flexible, formative and summative assessment (Broadbridge& Henderson, 2008).

To overcome the difficulties faced by the students in mathematics lessons, many engineering institutions have offered academic support services. The Mathematics Support Centers (MathCentre) of many universities in England give online courses, lecture notes, tests, videos for mathematics teaching at their web site for free (e.g. University of Loughbough, Coventry and Leeds). Loughbough, Manchester, Reading, Hull and Sunderland University have made the HELM project (Helping Engineers Learn Mathematics) between 2002–2005 years to enhance the mathematical education of engineering undergraduates by provision of range of flexible learning and teaching resources (Green at al, 2003).

Engineering students can also use the mathematics laboratories of some of the universities in the United States. (Deaware, MIT). Examples can also be given from Australia such as Adelaide University Maths Drop –In Centre, Queensland Technology University Math Access Centre etc.

From a survey of recent (from1995 up to the present time) literature in mathematics education for engineering students, following are notable means for teaching and learning to adapt to 21st century needs and conditions:

- use advanced computer based methods- web based interactive, software applications, or both,
- address student variability,
- take a multidisciplinary approach,
- use a Problem Based Learning strategy (Lopez, 2007, p.6)

Active learning means learning by doing. Active learning broadly encompasses all learning driven by the learner. The students' success will become higher when he or she participates to his learning process more (Nirmalakhandan at al., 2007, Lopez, 2007). Problem based learning and computer based learning is also classified as active learning.

With the rapid progress of computer technology in last couple of decades, software applications and the web have become important elements of the engineering mathematics education. The widely used software programs are Matlab, Excel, Minitab, Mathematica, Mapple, Mathcad (Broadbridge& Hendersen, 2008).

Cooperative learning in engineering mathematics education is one of the methods used and promotes the high success (Johnson at al, 2000). Variations and combinations of some learning methods such as project-based learning, the integrated approach, the four-leaf clover model are also used (Lopez, 2007).

Naturally, the changes of teaching and learning methods have affected assessment methods.

Additional assessment methods include a combination of some of these assessment methods; class tests, group projects, individual projects, written assessment and computer-aided assessment.

Continuous assessment gives to the educators a chance to have continuous information about the needs of the students and the class as a whole. With flexible assessment method student chooses his own evaluation method. This forces the student to have the control of his own learning and choosing the best method to show his success as much as possible (Wood&Smith, 1999).

As an example, mathematics courses content, teaching and assessment methods in the Mechanical Engineering Departments of Loughbough University are given below (Broadbridge&Henderson, 2008,p.58):

Table 1: Mechanical Engineering Program

Module	Credit	Pre req
Mathematics for Mechanical Engineering (MAA 310)	20	None
Mathematics for Mechanical Engineering (MAB 110)	10	MAA310

MAA 310: Mathematics for Mechanical Engineering

Content: Algebra of complex numbers, vectors and matrices. Solution of system of linear equations, determinants, matrices and Gauss elimination. Iterative solution of nonlinear equations (Newton Raphson). Elementary functions including hyperbolic functions. Ordinary and partial differential equation: techniques and applications including stationary values and errors. Integration: analytical techniques and Simpson's rule, applications (area, mean value, RMS, volumes of revolution). Ordinary differential equations: first order separable and linear equations, second order linear equations with constant coefficients, applications. Laplace transforms: application to solving ordinary differential equations. Sequences and series: infinite series, convergence, Binomial, Maclaurin and Taylor series.

Method of Teaching and Learning: Total student effort for the module: 200 hours on average.

Teaching & Learning: A combination of 48 one-hour lectures and 26 one-hour tutorials* with the remaining time for private study, working on problem sheets and revision for exam.

*Tutorials are where no new material is covered. Either students work through problems and get help from the staff on hand or else the lecturer goes through worked examples.

Assessment: Coursework: Eight computer-based or in class tests (8x5%= 40%). Summative Examination (60%) (3 hours).

MAB 110: Mathematics for Mechanical Engineering

Content: Elementary probability and statistics. Matrix eigenvalue problems, with application to solutions of Ordinary Differential Equations, for example vibrating systems. Optimisation of functions of several variables, with and without constraints. Fourier series and partial differential equations.

Method of Teaching and Learning: Total students effort for the module: 100 hours on average. A combination of 24 one-hour lectures and 12 one-hour tutorials with the remaining time for private study, working on coursework assignments and problem sheets and revision for exam.

Assessment: Coursework - 2 equal computer based tests (20%). Formal Examination (80%) (2 hours).

Conclusion

Engineering education is an important part of higher education. Mathematics teaching has a crucial role in engineering education. The recent developments in technology and computers have caused variation in teaching mathematics of engineering students and have brought with them the use of modern techniques and methods. Computer and internet can not be ignored in engineering education.

This research aims to shed some light on how the mathematics education, which is an important part of the engineering education for the 21st century engineers, must be, by investigating the curriculum, teaching and assessment methods.

References

Adams, P. A., Kaczmarczyk, S., Picton, P. & Demian, P (2007). Improving Problem Solving and Encouraging Creativity in Engineering Undergraduates. *International Conference on Engineering Education, Portugal*.

Broadbridge, P. & Henderson, S. (2008). Mathematics education for 21st century engineering students. Final Report. *Australian Mathematical Sciences Institute*. Available: http://www.amsi.org.au/.

Green, D., Harrison, M. & Ward, J. (2003). .Mathematics for engineers - the helm Project. *Conference on Strategies for Student Achievement in Engineering. UK*. Available: http://www.hull.ac.uk/engprogress/prog3papers/progress3_HELM_final.pdf

Gruenwald, N. & Klymchuk, S. (2002). Using Counter Examples To Enhance Students' Conceptual Understanding Engineering Undergraduate Mathematics: A Paralel Study. *Proceedings of the Second International Conference on the Teaching of Mathematics at the Undergraduate Level – ICTM-2. Crete, Greece. Wiley, ISBN: 0-471-46322-9.*

Henderson, S. & Broadbridge, P. (2009). Engineering Mathematics Education in Australia. *MSOR Connections 9(1): 12 – 17.*

Johnson, D. W., Johnson, R. T. & Stanne, M. B. (2000). Cooperative Learning Methods: A Meta Analysis. Available: http://www.tablelearning.com/uploads/File/EXHİBİT-B.pdf.

Lopez, A. (2007). Mathematics Education for 21st Century Engineering Students: Literature Review. *Australian Mathematical Sciences Institute*. Available: http://www.amsi.org.au/carrick.php.

Mustoe, L. & Lowson, D (Editors) (2002). Mathematics for the European Engineer A Curriculum for the Twenty –First Century. *SEFI Mathematics Working Group. SEFI HQ, Brussells, Belgium, ISBN 2-87352-045-0.*

Nirmalakhandan, N., Ricketts, C., McShannon, J. & Baret, S. (2007). Teaching Tools to Promote Active Learning: Case Study. *Journal of Professional Issues in Engineering Education and Practice, Vol. 133, pp. 31-37*. Available: www.spacegrant.nmsu.edu/NMSU/fac_deu/article2.pdf.

Wood, L. N. & Smith, G. H. (1999). Flexible Assessment. Proceeding of Delta 1999 The Challenge of Diversity- *A Symposium on Undergraduate Mathematics. Queensland*. Available: http://www.sci.usq.au/staff/spunde/delta99/Papers/wood_2.pdf.