# Teaching Maths in Context

## Signal/Digital Processing

## MATLAB-Based Minimal-Mathematics Introduction to Engineering Topics

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### *Abstract*

*The problem of declining mathematical skills and appetite amongst university entrants is well known. In order to soften the impact that this makes on student recruitment and retention in the School of Electronics at the University of Glamorgan, it became necessary to explore a 'minimal-math' or 'engineering-first' teaching approach. MATLAB-based graphical user interfaces, simulations and animations are employed to give students an unclouded insight into the engineering concept and the underlying physical considerations, and a clear appreciation of the interplay of the parameters involved. This type of first encounter helps to stimulate the students' interest in the subject, erects crucial knowledge pegs, and lays a solid foundation to support a more mathematically rigorous approach during later encounters with the topic when any deficiencies in math skills will have been remedied.*

### Level of Material: First Year and Second Year

## The Execution

This case study describes the teaching of multimedia communications, a module taken at Glamorgan by a very mixed cohort of honours and non-honours second-year students from various schemes, including Music Technology. The mathematical competence of the class is therefore varied, but generally significantly deficient in key areas. We attempt to deal with the situation by putting engineering first, aiming to first endear the students to the engineering concepts involved and their applications. In this way, maths is not inadvertently employed as a gatekeeper to the module, and an inappropriate level of maths content is avoided, which would leave especially this cohort of students feeling like they are being served a main meal of maths with some engineering for dessert. Once the students have an unclouded insight into the engineering concept and the underlying physical considerations, then some of the mathematical techniques required to precisely encapsulate the interplay of parameters are discussed. The approach generally avoids a lot of maths content, and aims to prepare the students to cope with the intellectual challenges facing the majority of practising engineers in the 21st century where ubiquitous software packages provide reliable solutions of common mathematical problems. To illustrate, consider the execution of the approach in teaching two common topics, namely signal sampling and frequency domain concepts.

To introduce signal sampling, we do not simply quote the sampling theorem and show its application. This would be tantamount to arming the students with a 'magic' formula that they can apply superficially to solve a standard engineering problem. Neither do we begin with a rigorous mathematical proof, involving a range of mathematical techniques, namely integration, Fourier transform, Parseval's theorem, impulse function and its characteristics, etc. This maths-first approach would be inappropriate to the cohort and many would disengage before reaching an engineering application of the mathematical discourse. Rather, we start the topic by discussing the engineering benefits of transmitting only the samples of a signal, and stir the students' interest and curiosity by asserting that the original signal can be perfectly reconstructed from the sequence of samples, provided we follow a certain rule. An extensive MATLAB-based animation lasting about 20 minutes is then employed to help the students to discover this rule, the type of device used for reconstruction and the natural penalty for flouting this rule. A foundation thus laid, the student can more confidently learn about anti-alias filter design, aperture distortion due to flat-top sampling and the practical issues involved in sampling. The maths involved in this subsequent treatment is mostly arithmetic and algebraic manipulations, and these are taught through worked examples.

To introduce the students to the frequency domain characterisation of signals, we do not begin with a mathematical discussion of the Fourier series, the Fourier transform and their properties. Rather, using a MATLAB-based graphical user interface, we enable the students to investigate a number of important topics including periodic signals and the sinusoid; Fourier synthesis and signal bandwidth; and time-frequency domain relationships. The software allows the student to pose and receive answers to a range of what-if questions, and to explore important engineering concepts. These include, among others, the effects of certain time-domain operations such as time reversal, signal delay and pulse shaping on signal spectrum. We impart this crucial appreciation of some of the key concepts that influence communication system design without the burden of abstruse maths. Emphasis is placed on the student acquiring a clear understanding of these concepts, while actual computation of Fourier coefficients is done using the MATLAB *fft* function.

## Pre-requisite Knowledge

Because of the diverse nature of the cohort taking the module, little mathematical background is assumed beyond GCSE Maths. Most of the mathematical ability required is developed just-in-time for each topic. Arithmetic and algebraic manipulations, sine function, logarithmic measures, etc are taught at various stages and reinforced using worked engineering examples.

## How Are Students With Different Mathematical Backgrounds Supported?

The maths required is taught at the point of need in an engineering context. Those students needing further help are identified during tutorial exercises and referred to the Education Drop-in centre. This is a central university resource located in the library and staffed four days a week for student consultation on maths problems. The centre also provides numerous free leaflets on a very wide range of maths topics that the students can pick up for home study.

## What Support Was Needed?

In-house training is provided at the beginning of each academic year for research students involved in the delivery of laboratory and tutorial classes. The author has been developing programs in MATLAB since 1992, but MATLAB is very easy to learn especially for anyone with a computer programming background. Furthermore, MathWorks runs regular training courses in MATLAB and also provides technical support to registered users. Students using the software developed for the module need only basic computer literacy to manipulate the user-friendly graphical user interface.

## The Barriers

An extensive use of the approach described in this case study is currently hampered by a lack of easy-to-use custom off-the-shelf software products designed to explore and simulate the engineering problem or concept of interest at a sufficient depth. In a classroom environment, nothing else beats a good computer simulation in engagingly demonstrating an engineering problem and the interplay of relevant parameters. However, developing the required software can be very time consuming and it is well worth searching the Internet for free web-based animations that may be relevant to the topic, although these will in general have some shortcomings.

## The Enablers

There were sufficient terminals running MATLAB software that students could access in their spare time. Students were given a series of exercises to try out using the software to pose a range of what-if questions and record their observations. For example, how is the amplitude spectrum affected by time reversal? Time delay? Pulse shaping? Duty cycle? Etc. How is the phase spectrum affected? What signal is reconstructed from a sequence of samples of a given band-limited signal as the sampling frequency is changed? When does distortion set in and in what form? Etc.

## Evidence of Success

Formal written feedback from a short course in digital telecommunications network for practising where the approach has been employed was very positive. Most felt that the approach made the subjects enjoyable and easy to follow. A similar evaluation will be undertaken at the end of the first year of adopting the approach for undergraduate teaching.

## How Can Other Academics Reproduce This?

This engineering-first, maths-second approach is applicable to any introductory engineering topic especially if it is traditionally wrapped in maths. First, the discussion emphasises engineering considerations throughout and presents with computer simulations an intuitively satisfying and insightful treatment. Then and only then is maths brought in for a precise quantitative statement of the important parameters and applicable physical laws.

## Quality Assurance

All modules offered in the School of Electronics at the University of Glamorgan are monitored and reviewed annually. Additionally, all assessment components are subject to both internal and external moderations.

### *References*


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