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A Review of Applied Mathematics

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Reviewing the Curriculum

Applied Mathematics is a subject which deals with problems arising in the physical, life, and social sciences as well as in engineering and provides a broad body of knowledge for use in a wide spectrum of research and industry. Applied Mathematics is an important school subject which builds students’ mathematical and problem solving skills. Applied Maths has the potential to build learners’ deep understanding of mathematical processes and therefore prepares students for university courses in engineering, science, and technology where similar skills in application and problem solving are required. However, this subject has unfortunately remained on the periphery of school time-tables and, without the commitment and enthusiasm of Applied Maths teachers, would likely be omitted from most school curricula.

The Applied Mathematics syllabus has remained the same since the 1970s. In 2014 the NCCA published a Draft Background Paper and Brief for the Review of Applied Mathematics [1] which was welcomed by academics in the field. In the School of Mathematics & Statistics in UCD, many of our third level colleagues have taken an active interest in this background paper and welcomed the invitation to put forward ideas for consideration in the new curriculum. In 2015 a school committee was convened and a school response to the proposal was written [2] and presented to the NCCA. With student learning at the core of our shared professions, and in order to communicate our objectives as third-level educators with our second-level colleagues, in this article we describe in broad terms our proposal shared with the NCCA.

Is there need for reform?

Considering recent Chief Examiner’s reports on Leaving Certificate Applied Mathematics, we feel there is definitive need to revise the intentions and content of this syllabus. The Chief Examiner’s report [3] from 2012 indicates there is a small, homogeneous cohort of students undertaking the same questions each year and also notes an embarrassing gender imbalance in the subject. This rather depressing situation exists in spite of the best efforts of enthusiastic teachers who motivate and encourage students to take the subject outside of the regular school timetable. Indeed, were it not for this goodwill among teachers of the subject, the situation would, arguably, be far worse. Nevertheless, the present review presents an opportunity to broaden the appeal and availability of Applied Mathematics. In UCD we consider this syllabus review as an opportunity to develop a high-profile programme that should be delivered within the timetable in the vast majority of secondary schools.

As with any curriculum reform, teachers should be supported prior to and during any revision of the syllabus [4]. The IAMTA has a strong tradition of supporting new and experienced colleagues in their practice and we believe their input and opinion should be considered and valued in the revision of the syllabus. It is also important that continued professional development, in the form of teacher community, should be supported and encouraged to match the revision of this important subject [5][6].

Is this course just an “add on” for students?

At present, Applied Mathematics is taken by less than 3% of students across the country. Teachers in this small portion of schools have worked tremendously hard to maintain this subject, teaching before and after school or during lunch breaks. This is not a satisfactory placing for such an important subject. Principals should be encouraged to include Applied Mathematics in the regular time-table in order to avoid the subject being seen as an “add on” course for CAO points instead of the important, core subject it is. The number of qualified teachers in the subject has been mooted as an issue, but with courses such as the new BSc in Mathematics and Applied Mathematics Education in UCD (DN200), and other similar teacher education programmes across the country, the popularity and availability of this subject should be pushed to the fore in post-primary schools across the country.

What exactly is Applied Mathematics?

As researchers and educators in Applied & Computational Mathematics, there is a feeling that the current syllabus in Applied Mathematics mischaracterizes the subject. Mechanics is only a subset of Applied Mathematics (albeit an important one) and Applied Mathematics, properly understood, implies the application of mathematical techniques to all problems in the physical and social sciences, and more broadly, in the economy and society. A contemporary professional applied mathematician might work in valuing financial derivatives, forecasting the weather, or computational engineering.
As third-level mathematics educators we feel that the new Applied Mathematics syllabus should not be used to bolster a mathematics curriculum but rather be viewed as a core ‘Further Maths’ subject for those who enjoy mathematics and may wish to pursue it at third level. Many of our conversations in recent years have revolved around the current lack of emphasis on calculus in the Mathematics curriculum and the negative effect this is having on undergraduate students in science and engineering. We believe that students’ lack of familiarity with calculus and the knock-on effect on their preparedness for third level [7] should be dealt with endogenously in mathematics and that an emphasis on calculus that was apparent in the curriculum pre-2010 can again be highlighted without compromising the pedagogical aspirations of the revised mathematics curriculum. Applied Mathematics could then build on students’ knowledge of calculus in introducing further topics within this separate syllabus.

**Proposed Core Topics**

Applied Mathematics cannot be separated from Mathematics in its wider context. Therefore, it is sensible (at least pedagogically) to include “core mathematics” (in the language of the draft review) in the proposed new programme. Again, this should only be done in the context of an Applied Mathematics education that can be delivered in the vast majority of secondary schools. For these reasons, we think it is sensible to include a mixture of core mathematics and application areas in the new programme. These topics should be chosen so as to complement the applications. Potential areas in core mathematics should include: vectors, ordinary differential equations, computational science, and mathematical treatment of mechanics with application areas which are as diverse as the range of topics in modern applied mathematics.

**Applications in Applied Maths**

On the applications side, the inclusion of a finite and static list of optional study topics (as included in the draft background paper [1]) could lead students to the mistaken conclusion that there is a single list of canonical topical areas comprising the whole of Applied Mathematics. This would be similar to the trap inherent in the current Leaving Certificate structure, wherein students confuse “Applied Mathematics” with “Mechanics”. Therefore, instead of having a static list of options, a possibility is to introduce “case studies” to be comprised of a non-exhaustive and evolving list of topical...
exercises in application areas, to be determined (and updated) by a consultation with industry, academia, government, and educational stakeholders. Industrial and Scientific participation in the selection of case studies could extend to the provision of course materials (data, instruction manuals, mathematical models, etc.), and written material for the case studies could be developed accordingly. Speaking again rather idealistically, a web portal for the case studies could be created, giving rise to the possibility of blended-learning approach suing online videos made by industrial and academic partners. This would support both teachers and students.

Figure 3: Interface profile of a liquid-liquid two phase flow generated by a high-resolution direct numerical simulation of the Navier-Stokes equations with the computational software. Lennon Ó Naraigh, UCD

Computational Science versus Computer Programming
A suggestion in our UCD response [2] to the draft proposal [1] relates to computational science. We suggest Computational Science should be included in place of a module on Computer Programming. Computer Programming is a subject in its own right, not an addendum to mathematics. Instead, Computational Science may be relevant to building students’ skills in using numerical methods to solve equations arising from mathematical modelling, and analysing and interpreting the results. By using open-source software such as Python (which is best practice in academic computational science), the cost of implementing this aspect of the new programme could be much reduced. The same principle could be extended to the hardware side, for example, by using the Raspberry Pi computer. Computer Programming may then be pursued in its own right as a Junior Cycle module or Senior Cycle subject.

Where do we go from here?
Summarizing, we have argued that a new approach to Applied Mathematics in secondary schools is worthy of consideration. As academics who work in a College of Science with a broad intake of students, and as promoters of education and research of Mathematics and its applications, we further believe that such an endeavour is worthwhile only if it leads to a broad take up of the new specification. If implemented in a way which supports teachers in curriculum reform, the new programme could lead to the required step change in making this core subject available to many more students. In particular, by introducing a new specification that simultaneously contains core mathematics (including the mathematical treatment of mechanics), existing second-level teachers of both Mathematics and Applied Mathematics could teach the new syllabus without requiring any additional up-skilling. At the same time, the new specification should be promoted as an essential subject for study of STEM subjects at third level. Finally, for those tasked with implementing the new programme, it should be a priority to obtain the goodwill of teachers and to secure academic and industrial “buy-in” (via the case-studies concept) of which we in UCD would be happy to contribute with our academic colleagues in other institutions. The ideal should be a programme that is deliverable in the vast majority of secondary schools, and should showcase the wonderful and diverse applications of mathematics in the world around us.


