Adequacy of pre-university mathematics curriculum as a preparation for a tertiary education in the sciences

Joseph N. Grima & Alfred J. Vella

Department of Chemistry, Faculty of Science,
University of Malta, Msida MSD 06, MALTA

E-mail: joseph.grima@um.edu.mt
Tel: (+356) 3290 2274 / 5
WWW: http://staff.um.edu.mt/jgri1/math.html

Schools:

- Provide future generations with a body of knowledge and skills that will enable them to live and advance in life.

- **At the barest minimum:** Provide pupils with skills in **numeracy and literacy** at a level necessary to function at work and in society in general *(UK Basic Skills Agency)*

Adequate Literacy / Numeracy = Difficult task:

1. Different students' strengths and abilities;
2. Different future career pathways.

   – Only a moderate percentage of students will eventually make it into tertiary education

   – Different university disciplines require different levels of expertise in literacy and numeracy

Different university disciplines require different levels of expertise in literacy and numeracy

1. Humanities/Laws/Biological science = little math (arithmetic & statistics)

2. Physical sciences & Engineering = much more mathematics (& more complex)

$$E_P = \frac{1}{4\pi\varepsilon_0} \times \left(-\frac{z^2e^2}{d} + \frac{z^2e^2}{2d} - \frac{z^2e^2}{3d} + \frac{z^2e^2}{4d} - \cdots \right)$$

$$= -\frac{z^2e^2}{4\pi\varepsilon_0 d}\left(1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \cdots \right) = -\frac{z^2e^2}{4\pi\varepsilon_0 d} \times \ln 2$$

Atkins & de Paula, *Atkins' Physical Chemistry* 7th edition , Ch. 23

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Scope of paper:

1. To investigate how well the education system in Malta is preparing its pupils for degrees in sciences by providing them with the appropriate mathematical skills;

2. To make a few suggestions on how this **important minority** can be provided with the **required** mathematical skills.

University of Malta Science programmes:

1. 'Pure' science degree:
   - **B.Sc.(Hons)** - Faculty of Science **

2. 'Professional' science-related degrees:
   - **Teachers: B.Ed.(Hons)** - Faculty of Education (science specialisation) **
   - **Pharmacists: B.Pharm.(Hons)** – Faculty of Medicine & Surgery
   - **Engineering: B.Eng.(Hons)** – Faculty of Engineering

(**) The only 2 courses where a 'pure science' is taken as a principal area

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UoM BSc(Hons) / Science BEd(Hons)

Students choose two principal subject areas from:

Biology – Chemistry – Computer Science –
Informatics – Mathematics –
Statistics & Operations Research – Physics

Note: Not all the combinations are possible

UoM General Entry Requirements:

➢ Passes at SEC (16+) level in Maltese, English Language and Mathematics.

➢ The 18+ 'UoM Matriculation Certificate' (MATSEC):
  1. Two subjects are studied at Advanced Level **
  2. Three subjects are studied at Intermediate Level (~ 1/3 of that of an Advanced Level) **
  3. Systems of Knowledge (General Studies)

** Must include at least one from each of these three groups:

Group 1: The Languages
Group 2: Accounts / Economics / Marketing / Computing & IT
Group 3: The Sciences

http://www.um.edu.mt/courses/

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Special Entry Requirements:

➤ Different courses can also have specific entry requirements by naming the subjects and the grades that should be obtained at A and I level.

➤ For BSc(Hons) & Science BEd(Hons) these depend on subjects chosen for study, e.g.:

Specialisation	Specific entry requirements
Biology	Biology (A) and Chemistry (I)
Chemistry	Chemistry (A) and Physics (I)
Physics	*either* Physics (A) and Pure Mathematics (I)
	or Pure Mathematics (A) and Physics (I)

Practical Implications:

(1) **'Chemistry and biology' undergraduates join the course with just an SEC standard in Math;**

(2) When both subjects are taken from 'physics, chemistry, computer science or IT', the entry qualifications include an I-Level in Math. – Is this sufficient? Experience says no.

(3) 'Biology + physics' combination is not possible because of specific entry requirements / MATSEC system.

The 'biology + chemistry' stream:

(1) Is math really required?

(2) What type of mathematics is required (the minimum)?

(3) What sort of mathematics training should be given?

(4) What sort of mathematics training are UoM chemistry and biology students actually getting, and is this sufficient?

The 'biology + chemistry' stream:

(1) Is math really required?

> SEC level math **may** be sufficient to for the biological component;

> SEC level math is **certainly unacceptable** as far as the chemistry component is concerned. ↓

University level chemistry <u>is meant to</u> include theories and models (usually mathematical models) to explain physical and chemical phenomena **!**

Chemistry … (1) Is math really required?

‘A facility in mathematics is an essential part of the armoury for all chemists.’

Mathematics in Chemistry Degree Courses –
The Royal Society of Chemistry, UK, Sept. 1996

Chemistry … (2) What math is required?

A chemist's <u>minimum</u> math skills must include skills in:

1. The handling of indices and logarithms;
2. Equations functions and graphs;
3. Differentiation and integration (including partial differentiation and differential equations);
4. Basic trigonometry (including trigonometric identities and polar coordinates);
5. Statistics, regression analysis and error calculations;
6. Vectors; *etc.*.

Mathematics in Chemistry Degree Courses – The Royal Society of Chemistry, UK, Sept. 1996

Chemistry … (2) What math is required? …

Topics range: From ones normally covered in some 16+ syllabi (e.g. indices) to others that are usually part of mathematics degree courses (e.g. partial differentiation).

Required proficiency: Students must have grasped the math to the extent that they can use it **with confidence** in their chemistry courses.

Chemistry … (3) What math training should be given?

Many foreign universities include math courses as part of their core 'chemistry' curriculum.

1. **University of Exeter (UK):** 15 ECTS credits in mathematics in their first year of undergraduate studies (25% of all credits in the first year);

2. **University of Bologna (Italy):** 17 ECTS credits spread around the first two years of study;

3. **University of Perugia (Italy):** About 40% of their first year.

Chemistry … (3) Entry Requirements & Math

Importance of mathematics in the chemistry curriculum is often reflected in the entry requirements for chemistry degree courses …

'Candidates should normally offer three A levels including chemistry and mathematics.'

Online undergraduate prospectus, University of London, Imperial College, UK

`http://www.ic.ac.uk/`

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Chemistry … (3) Entry Requirements & Math

'If you plan to take chemistry through to the second year and beyond, we recommend strongly that you have A level maths (or an equivalent) — AS is not sufficient.'

Web pages for chemistry teaching at the University of Cambridge, UK
`http://www-teach.ch.cam.ac.uk/introcourses/faq.html`

Chemistry … (3) Entry Requirements & Math

''There is however considerable concern regarding Mathematics. A proficiency beyond GCSE level is considered essential to the study of Chemistry at university level, and many of the colleges normally require A-Level Maths (with grade A or B).'

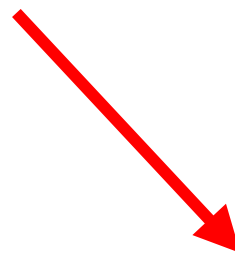Online undergraduate prospectus, University of Oxford, UK
`http://www.chem.ox.ac.uk/access/apply2.html`

(4) The math education of Malta's chemistry students

Pre-university math education

The math education of chemistry students at university

(4) The math education of Malta's chemistry students

Recall: **Math encountered in Chemistry topics:**

Includes topics that are above standard A-Level material

Math qualification on joining Chemistry programme:

SEC level – This may even be through a less demanding examination paper based on a somewhat curtailed syllabus (Paper B).
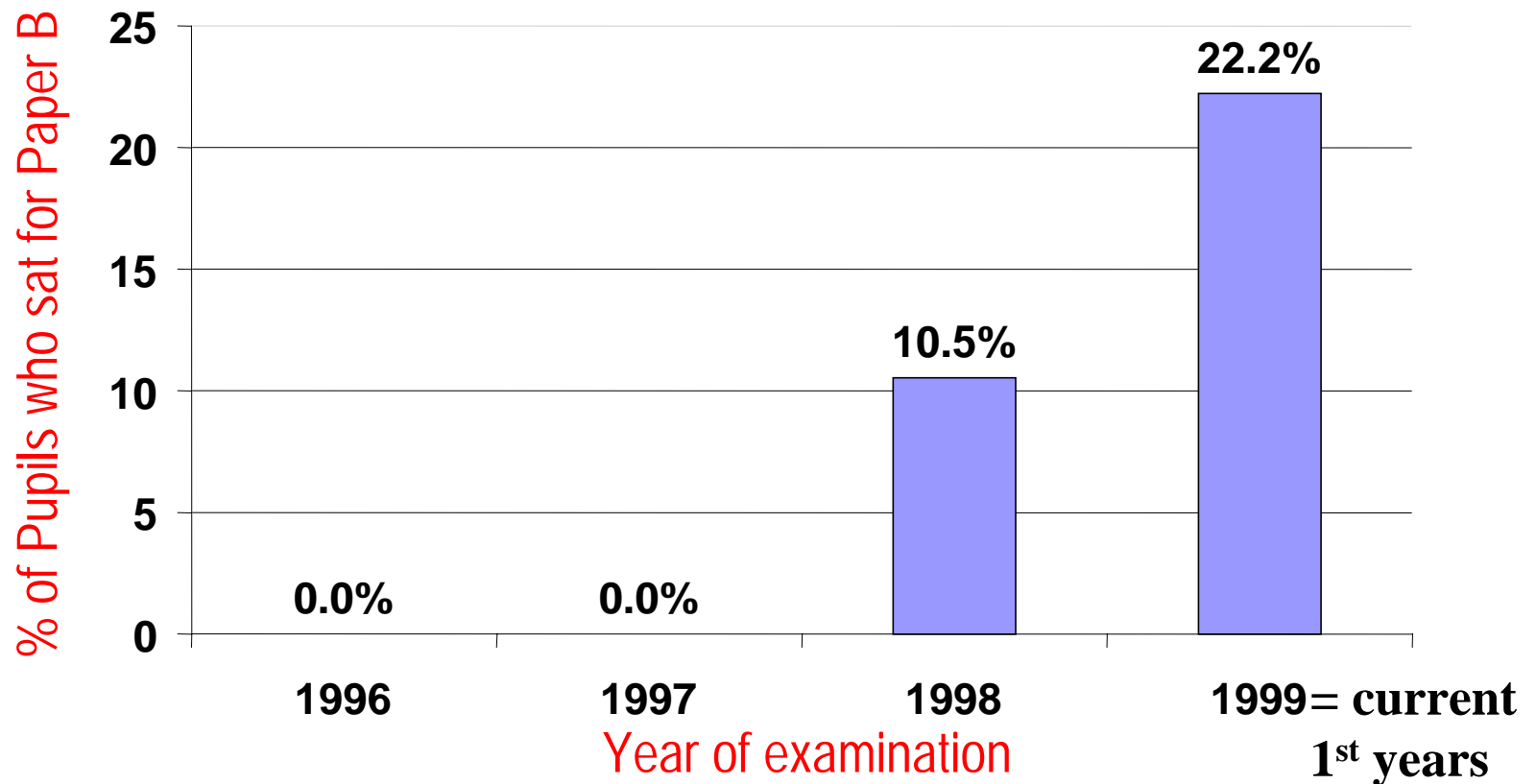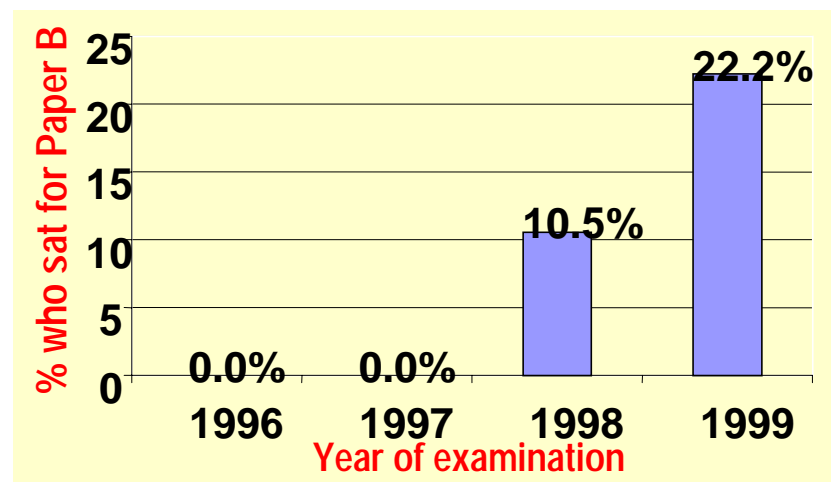
… PROBLEMS!!!

Problem #1: The 'Paper B' problem

There seems to be a trend for more students to opt for the easier 'Paper B':
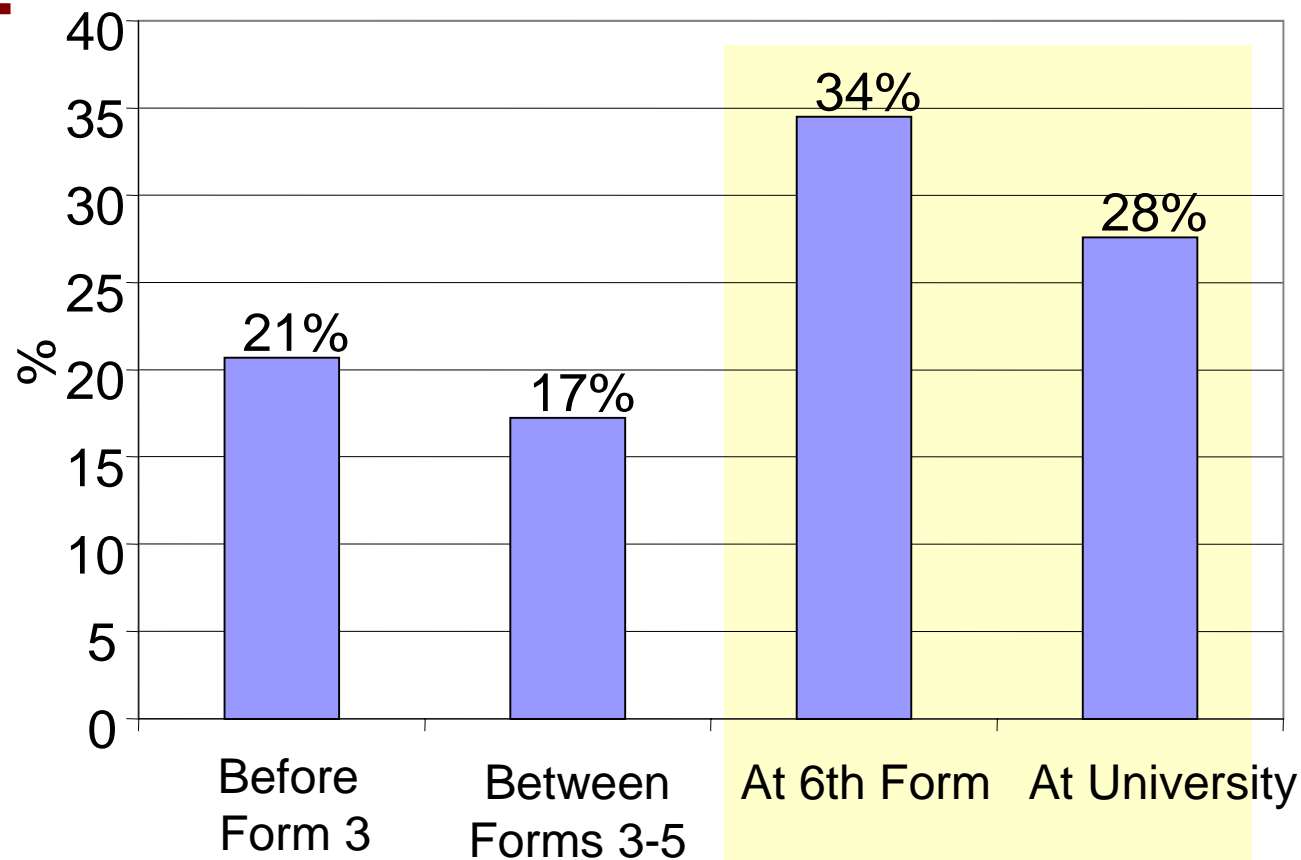
Problem #1:
The 'Paper B' problem

Why worry?

1. Science students may have then felt that their mathematical knowledge was not of high enough standard, *(or students were 'advised' to take the 'surer path' to a Grade 4)*;

2. **Students are not being made aware that chemistry and mathematics are inter-related**

Problem #2: When do students become aware that chemistry and mathematics are inter-related?

Bar chart showing percentages of when students become aware that chemistry and mathematics are inter-related:
- Before Form 3: 21%
- Between Forms 3-5: 17%
- At 6th Form: 34%
- At University: 28%

Too late ?

Problem #3:

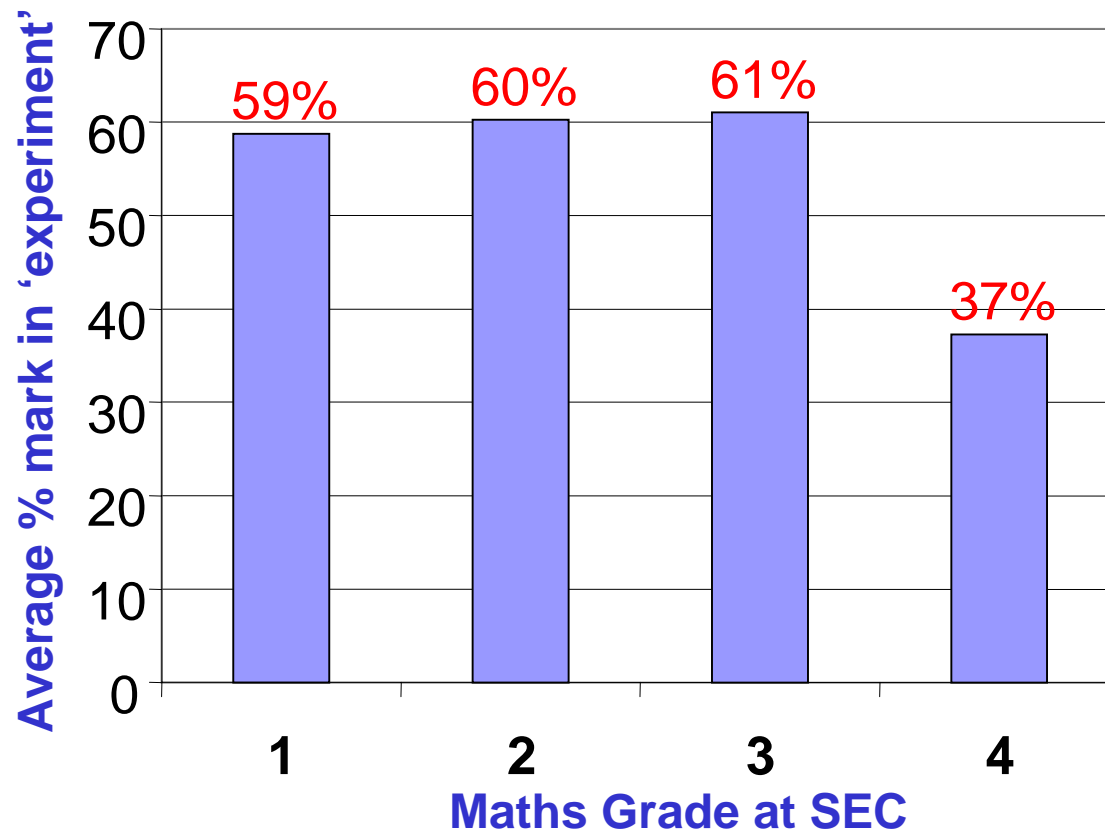## No mathematics for the two years preceding commencement of their university course!

Result: Most mathematical knowledge is difficult to retrieve from long-term memory.

Problem #3: No math for 2 years …

The experiment: 1st and 2nd year chemistry undergraduates students were asked to work a set of maths questions taken from SEC past-papers

The result:

Problem #4: Problems with basic algebra

The sides of an isosceles triangle are (3x-2y) cm and 2(x+y) cm. The third side is of length 3(x-3y) cm and the perimeter of the triangle is 46cm.

(a) Find the values of x and y.
(b) Calculate the length of each side.

Beyond the capability of most students !

Why is this happening?

1. Have things always been so bad?

2. Could this be the result of some recent change/s?

3. What could be giving rise to all this **‘mathematical laziness’**?

   ➢ The reduced amount of brain-teasing ‘Euclidean geometry’?

   ➢ The elimination of estimations and ‘back of envelope calculations’ (by allowing use of calculators for most math classes)?

Math education of chemistry undergraduates

Up to year 2000-2001:

Course followed: MA001 – Elementary calculus

When: First year, first semester

Content: General (not specifically designed for chemists)

Syllabus: Cartesian coordinates, equations of lines and curves, differentiation (including partial differentiation) and integration.

No. of ECTS Credits: 3 (i.e. 5% of First year)

Math education of chemistry undergraduates (up to 2000/2001) …

Problem: With MA001 alone, students could not cope with the math contained in the core chemistry courses.

Reason: (Main) Students' inability to do very basic algebra, such as, simplifying equations, working with indices and logarithms, factorising, etc.

Math education of chemistry undergraduates (up to 2000/2001) …

Possible causes:

1. Changes in SEC math syllabus: logs no longer included, 'index laws' covered only in Paper A, etc.;

2. Time:
    *   MA001 teaching time was too little;
    *   Not enough time to assimilate the material (MA001 was taught over a single semester.);

3. Problems in transferring the 'pure' maths learnt in MA001 to the chemistry applications.

Math education of chemistry undergraduates (From to 2001/2002)

The 'solution': <u>CH033 – Mathematics for Chemists</u>

1. Designed specifically for chemists
2. Taught through examples that chemistry students could relate to;
3. It was made sure that no math knowledge which the students did not have was being pre-assumed;
4. CH033 had more time and credits allocated to it:
   - 4 ECTS credits
   - Run over two semesters
   - Given ample teaching time (one hour of lecture + two hours of tutorials per week)

Math education of chemistry undergraduates (From to 2001/2002)

CH033 – Mathematics for Chemists

Does it work?

Test: Three months into the course, students were asked to sit for a 'closed book' test
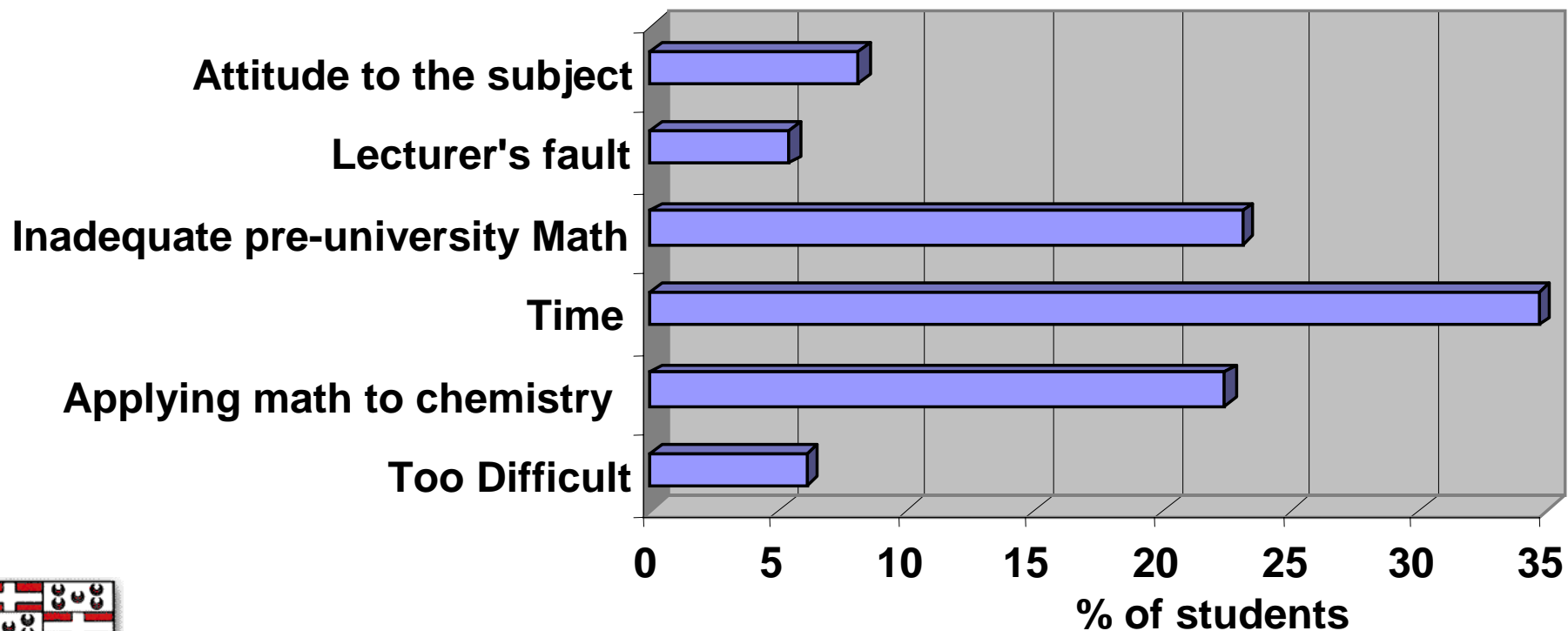
Result: Average mark was just 43%

WHY????

Math education of chemistry undergraduates (From to 2001/2002)

CH033 – Mathematics for Chemists

Why students thought they did so badly in the test:

Math education of chemistry undergraduates … The problem of time

In a joint-honours degree, the number of credits that may be allocated to 'math for chemists' is necessarily limited:

15 ECTS credits (as it done elsewhere) = more that 50% of total chemistry credits !!!

The math problem should be tackled before students reach the university.

Making the necessary changes

Ideally: All physical science undergraduates will have an A-level in pure math

In practice: MATSEC system of examination at the 18+ level does not allow this (with the existing 'joint-honours' degrees setup).

... However, there are a number of other changes that could be implemented ...

Making the necessary changes

(1) The introduction of a new subject at secondary school level (*"Further Mathematics", taught in parallel to the current math syllabus*).

(2) Sixth Forms start requiring a Grade 3 or better in math SEC from students taking science subjects at A-Level. (*or, to oblige those students with a grade 4 or 5 to take supplementary lessons in math*).

This will send the right signals to the students in secondary schools!!!

Making the necessary changes

(3) Changes in the Matriculation Certificate:

1. Is it wise to allow students aspiring to enter university to halt their mathematics education (and probably also that of Proficiency in English and Maltese) at the age of 16?

2. Can there be a regrouping of subjects to allow science students to attain higher mathematical skills through intermediate level mathematics?

Conclusions:

1. There are several inadequacies in the mathematical preparation at secondary and post-secondary level of education of those students who wish to further their studies in sciences.

2. However, there are also a number of possible solutions which could address the situation without causing major disturbance. Also, the time is right to make an effort to rectifying this particular problem which otherwise may actually worsen rather than improve in future.

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Thank you!

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