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DEVELOPING NEW QUANTITATIVE REASONING AND QUANTITATIVE PROBLEM SOLVING QUALIFICATIONS WITH POST 16 STUDENTS.

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Mathematics in Education and Industry (MEI)

The abstract nature of mathematics can sometimes lead to difficulties in designing a curriculum which serves, both as a basis for the further study of mathematics at university and for the personal and professional needs of individuals. This paper describes one approach to addressing this situation by designing a curriculum and resources to develop the quantitative skills considered to be necessary to live and work in a data rich society.

The need for quantitative reasoning and quantitative problem solving

In the UK, government, education and industry professionals, are aware that changes in the workplace and society are increasing the demands for mathematical knowledge, skills and understanding. A recent report “Count Us In” from The British Academy *(Mansell, 2015)* calls for structures to be put into place to enable the UK to rise to the challenge of becoming a data literate nation, starting with the education system. One example of an initiative in this area is the £19.5 million Q-Step programme aimed at developing undergraduate courses for social sciences which include quantitative skills.

The increase in computing power and developments in the internet and mobile technology, have made data easier to collect and communicate. This makes interpreting data a crucial skill for all citizens. The Royal Statistical Society report “A World Full of Data” *(Porkess, 2013)* makes 22 recommendations to a range of professionals and interested parties. It includes the statement below in its rationale:

> *“It is critically important that we equip our young people with the skills they will need to live and work in this data-rich world. This is true not just for their own well-being but for that of the country within the global economy.”*

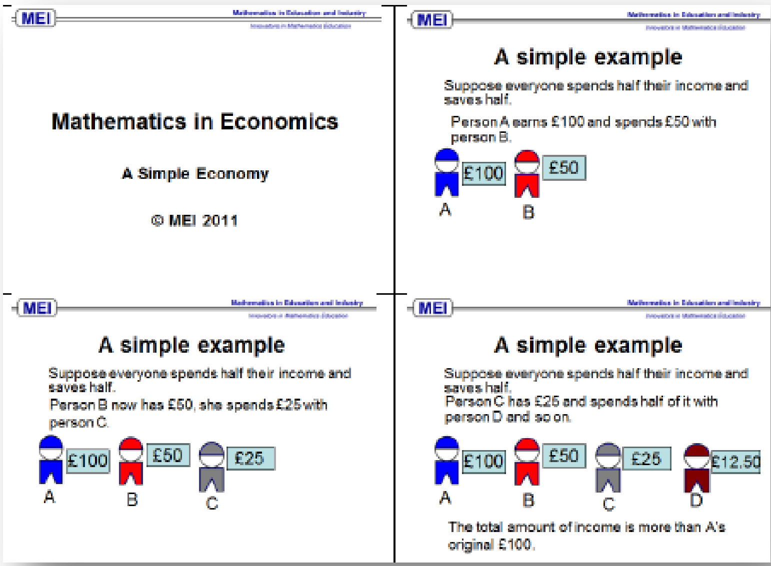
Books such as *(Paulos, 1990)*, *(Blasland & Dilnot, 2008)* and *(Gigerenzer, 2002)* suggest ways in which people are affected by innumeracy, in both their professional and personal lives. *(Rushton & Wilson, 2014)* acknowledge the challenge of having a single qualification, which is used both as a preparation for studying more advanced mathematics and for life & employment, suggesting a number of employers were dissatisfied with the numeracy skills of some new entrants. As a result of mathematics not being compulsory for post 16 students in the UK, this situation was exacerbated where students had not studied mathematics after reaching 16, but then entered employment later. This absence of mathematics from the post 16 curriculum detailed in *(Hodgen & Pepper, 2010)* also presented problems for some undergraduate courses in universities *(ACME, 2011)*. Responding to these needs, Mathematics in Education and Industry (MEI), an independent charitable UK curriculum development organisation, started a number of projects which will now be briefly outlined.

MEI's developments leading to innovative qualifications

Integrating Mathematical Problem Solving (IMPS) was a project funded by the Clothworkers' Foundation that aimed to raise awareness of the mathematics used in a variety of existing post 16 courses, provide important skills for both higher education and employment, and inspire students. The outcomes of the project *(Dudzic & Stripp, 2012)* included a set of free resources and ideas for further curriculum development. Here is an extract from a resource :

A model of a simple economy

Consider a simple economy where everyone spends half their income and saves the other half. This is not realistic but reality is complicated and we need to simplify it to help us understand it. We will make things gradually more complicated.



The Powerpoint continues to develop this theme geometrically, concluding with the ideas

- *Money circulates in an economy*
- *If the amount spent in the economy increases, some of the money spent will be paid to other people and then spent by them. So the total increase in spending is more than the initial increase*
- *The injection is the initial increase in spending. Multiplying the injection by the multiplier gives the total increase in spending.*

(Dudzic & Stripp, 2012) pp40

In response to the need for data literate citizens, MEI worked with the UK awarding body OCR, to develop an entirely new post 16 qualification, called Introduction to Quantitative Methods. Designed as a 60 hour course, it focused on developing and using mathematics in realistic contexts related to the needs of employers, specific higher education courses and the individual needs of a citizen. The course content included; use of ICT, modelling, statistics, finance, working with exponentials, working with graphs and gradients, and risk. In his weblog, *(Gowers, 2012)* Professor Sir Timothy Gowers added to the debate started by reports including; *(Hodgen & Pepper, 2010)* and *(ACME, 2012)* regarding making the study of mathematics compulsory for all 16-19 UK students. In *(Gowers, 2012)*, he offers suggestions on the mathematical content and a different teaching approach, suggesting that the lesson should start with a Socratic style discussion of a question which is interesting to the students and arises from real life, rather than a question designed to force them to learn some mathematics, adding that the mathematics should emerge because it helps to give a better solution. With this approach, the teacher's role is, when required, to subtly steer the discussion with prompting questions designed to make students consider the problem in greater depth. Gowers' ideas provoked a lot of interest from the mathematical community, enabling MEI to secured funding from the Department for Education to develop these ideas further, in a project called "Critical Maths".

Critical Maths combines elements of critical thinking with mathematics. Typically, students will be given a starter question which may, on the surface, not appear to them to be mathematical at all. In our classroom trials, the type of question which required an initial opinion or gut feeling response tended to produce a more fruitful discussion than asking for a mathematical approach from the outset. The teacher could then subtly move the discussion towards considering mathematical concepts.

In one trial lesson, the students were initially asked "do speed cameras reduce the number of road traffic accidents?" The teacher then explained that to prove their effectiveness traffic cameras had been placed on stretches of road which had the highest number of accidents in the previous year. When checked one year later, the number of accidents on almost all of these stretches had reduced. The students were asked, "is this convincing evidence of the effectiveness of the cameras?" After further debate, the students did a quick simulation. They each rolled two dice and everyone with a score of 10 or more was informed that they were accident black-spots. The accident black-spot students were given a cut out picture of a speed camera and told to roll again. After observing that almost all of the scores from this second roll were lower than the first roll, the class was asked whether they believed the paper cut out cameras had reduced the number of simulated accidents. It was immediately obvious that they had not, the idea that possibly some of the real accident reduction may be due to chance, emerged. This starting point led to further lessons on topics such as, regression to the mean, how to gather robust evidence, and randomised controlled trials. All of these are important concepts in understanding the role and limitations of evidence in decision making as explained in *(Sutherland, Spiegelhalter, & Burgman, November 2013)*.

New Qualifications

MEI brought together its work from IMPS, Quantitative Methods, Critical Maths and the ideas in *(Porkess, 2013)* into two Core Maths qualifications called Quantitative Reasoning, and Quantitative Problem Solving. As well as statistics, these qualifications include work on financial maths, Fermi estimations, exponential growth, logs, risk and many other useful concepts. It is an aspiration of the English government that up to 200,000 students across the country will go on to study one of the new Core Maths qualifications, either the MEI developed specifications or one of the alternatives offered by the UK awarding authorities.

In Summary

At present a large proportion of mathematics curriculum time in England is devoted to developing competence in performing mathematical calculations accurately and developing an understanding of mathematical concepts, which are important for both numeracy and the further study of mathematics. Mathematics is not compulsory for post 16 students in England leading to a situation where a significant proportion of people entering University or employment have difficulty with mathematical and statistical literacy. We hope that the new Core Maths Qualifications begin to address some of these issues. Evidence from the trialling of the Critical Maths materials and curriculum suggest that students are enjoying this approach but a more detailed evaluation is required.

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