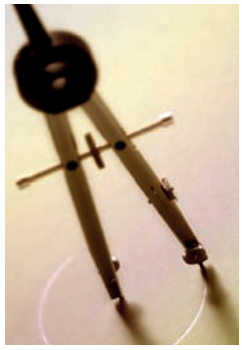
ACME Advisory Committee on Mathematics Education

Post-16 in 2016

Proposals for 16-19 Mathematics in anticipation of the review of qualifications scheduled for 2013 with resulting changes to be implemented from 2016

July 2010



EXECUTIVE SUMMARY

At the age of 16, young people make choices about their course of study which will affect the rest of their lives. It is therefore critically important that suitable options are available to them. This is not just a matter of allowing them to fulfil their potential, important though that is, but also of meeting the national need for a workforce that is highly and appropriately educated.

Reflecting the importance of this phase of learning, it is hoped that the government will proceed with the scheduled review of post-16 qualifications due to take place in 2013, with a view to implementing any resulting changes from 2016. This is sufficiently far in the future to allow the rare luxury of radical thinking about the full picture, as well as allowing any prospective changes to be properly developed and introduced.

With this in mind, ACME has been working with the mathematics subject community to consider the post-16 educational landscape and produce recommendations to inform further work in this area.

There are several key points on which there is an emerging consensus:

- Far too many students abandon mathematics at 16 and then find their progression hampered at a later stage by a lack of mathematics. The long term aim should be that mathematics should continue to be studied in some way by all up to the age of 18.
- There is a need for a larger pool of students with a substantial study of mathematics at Level 3 to enable many higher education courses to increase their mathematical demands to match those of similar courses internationally.
- The set of pathways for mathematics post-16 is inadequate, in that it fails to account for the variety of forms of employment and further study which rely on mathematical understanding and does not provide for the full ability range either at Level 3 or at Level 2.
- The provision post-16 is not easy to navigate and, outside A-level, lacks a sufficiently recognised currency.
- There is a need to recognise achievement at the highest level by retaining something equivalent to the Advanced Extension Award which requires sustained and deep thinking.

To address these points ACME proposes that:

1. Three Level 3 pathways in Mathematics should be established, along with a broad Level 2 pathway, to allow all students to continue with mathematics post-16 at an appropriate level of sophistication and volume.

2. In order to create an environment in which mathematics is seen as an essential element of post-16 study, an overarching Level 3 qualification should be developed to encompass all post-16 learning. The working title Baccalaureate is used to indicate a qualification which is a coherent package with some universal features, including in particular the opportunity to follow an appropriate mathematical pathway throughout the period.

These two recommendations are described more fully overleaf. It is the general principles and broad outline which we are setting out at this stage, together with an indication of the strategy for taking these ideas forward. Substantial detailed work would be required to implement these proposals.

BACKGROUND

This work is the final step of ACME's Level 3 Mathematics project, and has been developed using valuable contributions from representatives of all areas of mathematics, including employers and higher education, provided through workshops in November 2008, March 2009, June 2009 and March 2010, as well as through responses to the ACME discussion paper *Towards Level 3 Mathematics in 2016*[1] published in October 2009 and the ongoing *STEM advisory forum*[2] discussion.

No document of this type is ever the last word, and in particular the 'top down' aspect of the *Mathematical Needs*[3] project which ACME is currently undertaking – which is intended to inform revision and development of the 16-19 mathematics curriculum – will provide evidence as to what mathematics is needed at work, in Higher Education (HE) and in life in general. The current paper aims to lay down basic structures while the *Mathematical Needs* project will inform the content of the various elements following extensive research with employers and members of many subject areas in HE.

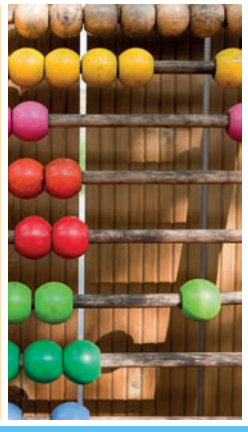
Because ACME's remit does not extend to mathematics education beyond the age of 19, this document concentrates on the provision for those up to the age of 19. However, it is clear that there is also a need for provision for adult learners, either as a second chance or to support a change of career direction.

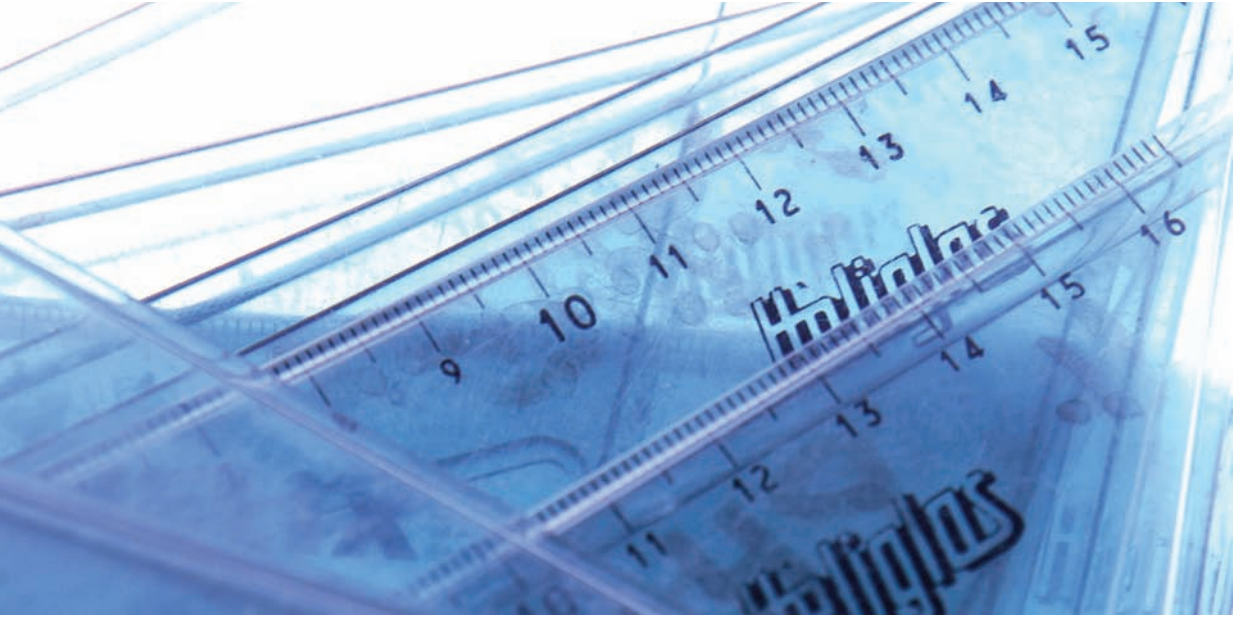
Our aim is to build a coherent framework of qualifications which will have recognised currency and provide for the full range of users. We understand a reluctance for dramatic change and, where possible, existing qualifications should be used to construct the pathways to avoid unnecessarily complicating the post-16 landscape. We hope that the greater flexibility of structures which will be developed will mean that in future small changes can be made without disproportionate upheaval.

1 See **www.acme-uk.org/downloaddoc.asp?id=175**

2 See The STEM Advisory Forum **www.stemforum.org.uk**

3 To learn more about ACME's *Mathematical Needs* Project: **www.acme-uk.org/page.asp?id=47**





1. Post-16 pathways in Mathematics

The mathematics courses available need to provide clear pathways for students which they and their advisers can readily understand and navigate. Gaps currently exist in post-16 mathematics provision, while there is also overlap (for instance between A-levels and some diplomas) and a lack of both coherence and clear comparability for target students. A rationalised provision which keeps students' options open yet provides sound bases for progression and/or transfer from one pathway to another is needed; further it needs to be one that is practical to deliver in schools and colleges, and provides known outcomes and clarity for stakeholders. As a basis for our proposals, we have assumed that the vast majority of those proceeding to further study of mathematics from 2016 will have had the benefit of having studied for the twinned pair of GCSEs in Mathematics which are being piloted from 2010.

OUR RECOMMENDATION IS THAT THERE SHOULD BE THREE PATHWAYS IN LEVEL 3 MATHEMATICS (WITH WORKING TITLES PATHWAY B, C AND D), AND A POST-16 PATHWAY IN LEVEL 2 MATHEMATICS (WITH WORKING TITLE PATHWAY A).

The mathematical skills developed should be appropriate for the needs of students on the different pathways, including mathematical thinking, problem-solving, logical argument and constructing a proof as a chain of reasoning. The assessment associated with each pathway should support these skills. Real care should be taken to provide coherence, with connections built in to the structure to avoid fragmentation. The provision should be designed so as to meet the needs of vocational learners (including those who will be required, perhaps against their inclination, to continue in education or training until 18) as well as those pursuing more academic goals. Mechanisms for transfer between pathways should be built in, with bridging materials or courses provided to facilitate such transfer. The model proposed, whilst radical, is not intended to be revolutionary and elements within it can be recognised as being developments of existing provision.

Each pathway would lead to a carefully constructed qualification which can readily acquire a recognised currency. Students would move through these pathways at different speeds depending on their prior learning and their aptitudes, as well as on the number of hours of study each week. In designing the provision, consideration has been given to the particular needs of those who have either just missed the Level 2 threshold or narrowly achieved it, so that they are provided with courses that enable their progression. Opportunities have also been provided for the most able mathematicians to be stretched and challenged. All the pathways would have intermediate exit points which allow recognition for what students have achieved up to that point.

In this document, Pathway A is described in less detail than the others. It covers a larger proportion of the cohort from those who have not achieved even the lowest grade at GCSE through to those on the C/D borderline. It also covers a wide variety of users of mathematics, many of them taking vocational courses. Thus at this stage Pathway A is an umbrella title and a large amount of detailed work will be needed to develop it. The underlying aim of providing these pathways is to empower individual students to gain mastery and appreciation of mathematics at as high a level as possible. Information, advice and guidance will need to be developed to ensure that these new learning pathways, and the opportunities they open up for many learners, are fully understood. With suitable guidance, students should be able to select their own pathways, and generally be encouraged to err on the ambitious side rather than be categorised as having limited potential in mathematics. Emotional and motivational issues which may have impeded progress at an earlier stage should not necessarily be recognised as permanently disabling, because moving into the post-16 phase can allow a fresh start. There is a role for diagnostic testing for learners embarking on and proceeding through these pathways and it is important that this be used positively rather than in a narrowly prescriptive way.

The structure of the pathways is shown on the accompanying diagram, along with their entry points and how they relate to each other. Rough equivalents to existing qualifications are also indicated where they exist.

The elements of the pathways are labelled by level of sophistication and volume. Within Level 3, five sub-levels of sophistication have been indicated by the minimum level of achievement desirable at the start. (These starting levels would not be too rigidly applied; bridging material should be available for motivated students.)

SUB-LEVEL	TYPICAL PRIOR LEVEL OF ACHIEVEMENT ON ENTRY
3a	GCSE Mathematics Grade C in one of linked pair
3b	GCSE Mathematics Grades BC
3c	GCSE Mathematics Grades BB
3d	AS level Mathematics
3e	A-level Mathematics

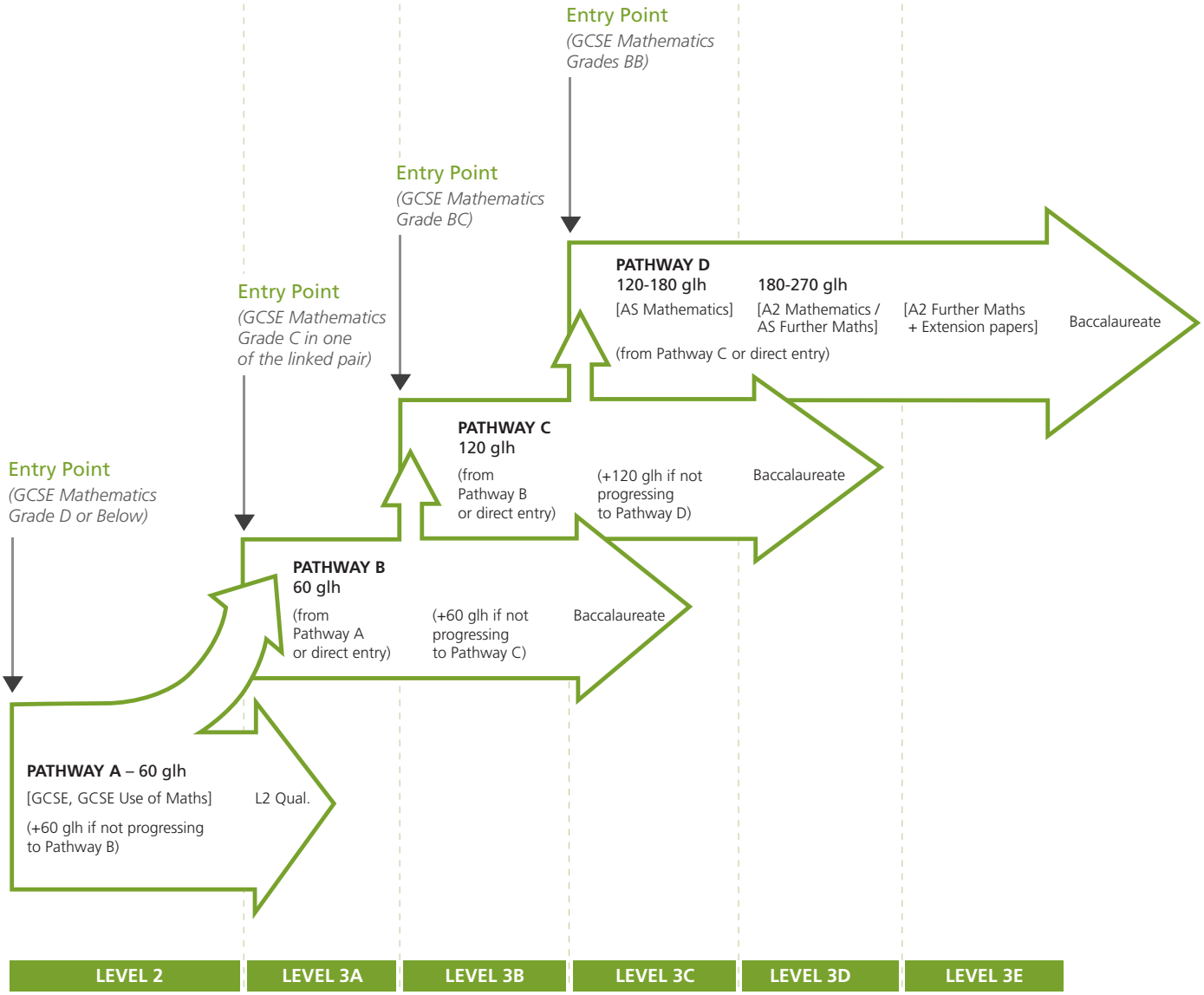
Volume is indicated in Guided Learning Hours (glh). (A full A-level corresponds to 360 glh, a single module to 60 glh.) These hours are a rough guide rather than a precise prescription and, in addition to face-to-face classroom time, might include activities such as directed use of interactive online teaching materials and industrial placement.

Some standard routes for transition between pathways are indicated. Additionally, some students, whose progression at Level 2 had been reduced for some reason, might be enabled to transfer more quickly to higher pathways.

Where possible students should take mathematics at as sophisticated a level as possible, so that, within practical limits of providers, each pathway should be available on a basis of two hours of study a week as well as at a higher rate in the case of Pathways C and D.

There is a tension between the desire for a coherent, holistic approach, building in relationships with other subjects, and modularity which can provide motivation and maintain a sense of achievement. The level of modularity will be adapted to the learners on each pathway, being greatest for Pathway A and least for Pathway D.

Sub-levels and typical prior level of achievement on entry



PATHWAY A

This pathway would be likely to be studied for about two hours a week. After one year many learners should be able to progress to the first year of Pathway B, but provision for a second year of Pathway A study should also be made for those for whom this is not a realistic possibility.

This pathway would be designed to give a qualification equivalent (both for employers and for progression purposes) to GCSE mathematics, but would not simply be a repeat of GCSE. Materials adapted to more mature learners with an appreciation of more contexts would be developed, and the use of spreadsheets and other software would be integrated. Project work would be included in this pathway.

PATHWAY B

This pathway would be likely to be studied for about two hours a week over a two-year course. It would provide the opportunity for all Level 3 learners to keep alive and develop their mathematical learning. It would be accessible to those having a Level 2 GCSE, and much of the content might involve considering material encountered at Level 2 in a Level 3 manner, reinforcing it in new contexts. The students pursuing this pathway would typically be pursuing progression goals which were not seen popularly as involving mathematics, such as arts-based degrees, child care, hairdressing, nursing and plumbing. Some of the learning would be contextualised appropriately and this could be within the students' principal lines of learning or other interests; the assessment also would accommodate such contextualisation. As well as addressing progression needs, be it into employment or further education, the pathway would help students develop mathematically as citizens with topics such as personal finance and understanding and using statistics (including a critical appreciation of how they are presented and interpreted in the media). Other aspects that might be included are estimation, the importance of checking and taking responsibility for one's answers, recognising the limitations of the models one has applied, encouraging in students a careful and reflective approach to their mathematics and the appropriate use of computer software, such as spreadsheets. Those who are successful and motivated to do so should be able to transfer to Pathway C for the second year of post-16 study, possibly taking a suitable bridging course.

PATHWAY C

This pathway would typically be studied for about four hours a week over a two-year course. This would provide support for students for whom mathematics was a significant but ancillary rather than central aspect of their focus of study, or where too high a level of technical proficiency is not required. They would be using mathematics as technicians, applying and developing models, rather than creating the models in the first place. (They would develop the skills to work with those following Pathway D and be able to communicate numerical information to those following Pathway B.) The motivation of such students may well be principally the application of mathematics to their main areas of study; the pathway would recognise this and stress the applicability of the mathematics involved. The pathway would place basic mathematics in a more adult context; modelling and comprehension would be central. Students would learn to make intelligent use of computer software, including computer algebra, graphing software, statistical packages and spreadsheets. As well as covering the general goals of Pathway B, topics covered would include the ideas of calculus, exponentials and logarithms, as well as a substantial amount of data handling. There would be opportunities for contextualisation and links to other subjects. The course would be likely to have some elements in common with present AS Use of Mathematics courses and also with some Level 3 FSMQs.

This would be a substantial course and it would be important to ensure its coherence and clarity of purpose. Although opportunities would exist for differing contextualisation, the mathematical content and assessment would be common for all learners pursuing this pathway. The assessment would contain a synoptic component which would assess students' abilities to connect and apply ideas. An extension paper could be provided to stimulate and challenge the most able students pursuing this pathway.

It would be desirable that courses for Pathways C and D were structured in such a way as to make transfer between them feasible in the early part of the course, so that as learners became familiar with the study of mathematics at Level 3, they could reconsider their chosen pathways.

PATHWAY D

This pathway would be likely to be studied for about six hours a week over a two-year course. Some students might (possibly by devoting more time to mathematics) progress rapidly and hence take an extended form of this pathway. It would provide for students for whom mathematics was central to their learning, because of intrinsic interest or because of it being a vital part of their desired progression. Such students might typically proceed to read degrees in mathematics, the natural sciences (biological and physical), engineering and many economics, financial and social science courses; among them would be found the future mathematical modellers. It is envisaged that the bulk of those presently taking AS and A-level Mathematics or Further Mathematics would pursue this course and it would contain many elements currently found in these courses, both in terms of content and the sophistication of the treatment thereof. The pathway would subsume within it the mathematical content of Pathway C, taking a deeper and more abstract approach and developing it further. There would also be additional content, which could allow an element of personalisation, including an opportunity to choose content relating to the student's other areas of study. As well as developing a body of technical knowledge, students would become adept at constructing and communicating mathematical arguments, developing proofs and using mathematics to model and solve problems.

Assessment would include a synoptic element on the common content. The possibility would exist, in some cases, of the additional content being assessed by a project which allowed integration with the learner's other subjects. There would also be extension papers to stimulate and challenge the most able learners. To encourage coherence and a holistic view of mathematics, the assessment would consist of a relatively small number of larger units, most of which might be taken towards the end of the course.

IMPLEMENTATION

While almost all of Pathway D exists already, and further development of Use of Mathematics and Statistics GCE AS and A-level modules, together with FSMQ, may assist in building Pathway C, a considerable curriculum development project, on a scale unprecedented in recent times (informed by expertise from industry, HE, Further Education (FE) and schools) will be needed to develop and implement the proposals made here. The ACME *Mathematical Needs* project will provide valuable input on content and process. Within each pathway, it will be necessary to address the considerable range of ability of students, and their very different rates of progression. These issues will be most severe in Pathways A and D.

There are of course resourcing implications, particularly with respect to the supply of teachers. A general increase in resource for the 16-19 age group is anyway implied by the requirement that all should continue some form of education or training until 18. We recommend that part of this resource is used to begin to develop existing teachers (not simply of mathematics, but also of subjects which require mathematics) to be able to provide teaching for Pathways A and B.

Many experienced teachers of mathematics will find themselves faced with fresh challenges in introducing these pathways. It is vital that they are provided with the professional development which gives them the skills and confidence to enable and motivate students. In particular, much reference has been made to contextualisation and links with other subjects; support will need to be given to teachers (and not just mathematics teachers) to develop cooperative teaching across subjects. Attention will also need to be given to helping mathematics teachers develop more holistic approaches to the teaching of the mathematical topics themselves.

Although in these proposals we have stopped short of suggesting that mathematics should become a compulsory subject for all until 18, it is clear that it is increasingly felt that, from the national perspective, this should be the case and in implementing these proposals this should be a long-term goal. For instance the recent report of the CBI Higher Education Task Force *Stronger Together*[4] includes a recommendation that Government should ensure that all young people, regardless of what route they choose, study some form of mathematics or numeracy education after 16. We hope that a virtuous circle could be created where, as more students continued mathematics beyond 16, there would be more teachers equipped to teach mathematics at all levels.

The effective and efficient delivery of a curriculum incorporating the pathways proposed may well have consequences for the local organisation of educational provision 16-19 (and possibly beyond), in particular to warrant sufficiently large cohorts to ensure viability of the full range of pathways.

A key element will be the development of high quality teaching and learning materials, both their generation and their dissemination. In establishing the assessment arrangements for these pathways, it is desirable to ensure that there is not unnecessary fragmentation of the market. For Pathways A and B particularly, assessment which includes coursework is likely to increase motivation, and teaching in context will be important. It is also important that mathematics is presented in a way which makes its transferability to other contexts clear[5].

None of these pathways will be able to be studied with paper and pencil alone. It will be vital that students have ready access to appropriate technology so that it can be freely incorporated in their lessons (and other learning experiences).

The increased uptake of mathematics post-16 should be welcomed by employers and should enable universities to make it clear where a course requires some mathematics without feeling that potential students will be deterred from studying such courses.

4 Stronger Together: Businesses and Universities in turbulent times. CBI Higher Education Task Force. **www.cbi.org.uk/highereducation**. September 2009. ISBN: 978-0-85201-707-4

5 A useful resource here is Learning Mathematics in Context. **http://tlp.excellencegateway.org.uk/tlp/xcurricula/lmic/**

2. Baccalaureate

This recommendation concerns the place of mathematics within the curriculum as a whole. Mathematics underpins study in many areas as well as being a subject worthy of study in its own right. Those who drop mathematics too early can find routes barred or unnecessarily hard at a later stage.

While A-levels have many strengths, a free choice of say four A-level subjects from a long list will not always lead to a coherent programme even for those capable of study at this level, and may mean that some for whom some mathematics would be desirable are discouraged from taking mathematics because it would limit choice in other areas. The programme of Level 3 diplomas may provide coherence but is leading to a proliferation of structures which inhibit transferability and demand early choice of focus which may limit progression routes. The proposed system aims to incorporate the best features of both systems, and provide a currency for the elements within the Baccalaureate which values study in mathematics appropriately. The value of something less than a full A-level (or AS-level) in mathematics must be recognised for what it is rather than dismissed as a soft option.

OUR RECOMMENDATION IS THAT, IN ORDER TO CREATE AN ENVIRONMENT IN WHICH MATHEMATICS IS SEEN AS AN ESSENTIAL ELEMENT OF POST-16 STUDY, AN OVERARCHING LEVEL 3 QUALIFICATION SHOULD BE DEVELOPED TO ENCOMPASS ALL POST-16 LEARNING.

While our motivation for such a qualification comes from mathematics, we believe that it is desirable for wider reasons, noting for instance the recommendation of the Nuffield Review of 14-19 Education and Training for the development of 'a unified and inclusive qualifications framework that embraces different forms of learning and promotes more effective choice and greater breadth of study'. The prestige of the International Baccalaureate, and the high standing of many international school-leaving qualifications such as the French Baccalaureate and the German Abitur, suggest that our proposed qualification could retain the perceived 'gold standard' of A-level while improving preparation for higher education and employment in many fields.

We envisage that learning at Level 3 in general education would be based around programmes typically of six subjects. Some of these subjects could be taken in larger volumes than others. All students should have the opportunity to study English and Mathematics as part of their programmes, and be encouraged to do so. To support this, courses would be available in English and Mathematics at several levels and in various volumes as in the pathways described on page 5.

Students achieving an appropriate standard in English, Mathematics and four other subjects would be awarded a Baccalaureate; this would be a pass/fail qualification and its title would not be endorsed to indicate the areas of study. Such an overarching qualification would be a means of bridging the academic-vocational divide. The qualification would, among other things, represent the successful completion of initial learning at Level 3 for 16-19 year olds. It would be expected that students progressing to higher study would achieve it (but it would not be an absolute requirement so as to avoid preventing the progression of those whose abilities have a very spiky profile) and higher education admissions systems would reward its achievement. Provided that this represented progression from achievement at 16, Pathway A could contribute to a successful Baccalaureate.

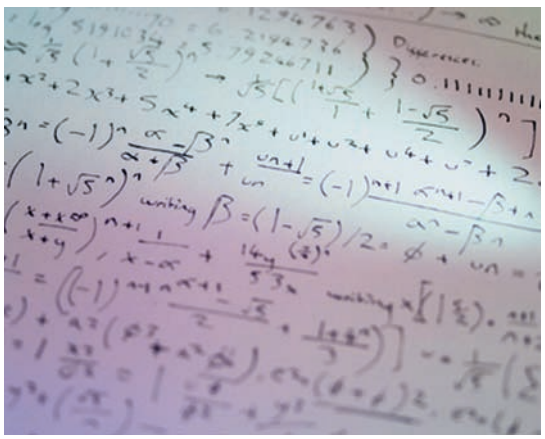
The fine detail of the Baccalaureate would need to be developed with a range of stakeholders, but we envisage that all students would have, regardless of whether they achieved a Baccalaureate or not, a Transcript. This would record both participation and achievement, including activities beyond those being pursued for the Baccalaureate; it would give the student formal recognition, as much as the student wished, of all her or his achievements. A credit framework would be established so that, in as far as appropriate, for each entry in the Transcript there would be an indication of volume, sophistication of demand (on a finer scale than the present NQF Levels) and standard achieved (as a standardised score). The means of assessment of the standard achieved would be appropriate to the activity in question and would avoid the inappropriate atomisation of learning outcomes.

The achievements on the Transcript would not be aggregated, except as deemed necessary for determining whether the Baccalaureate was to be awarded. Initially this might encounter some opposition from end users, but in time we believe they would see the benefit of having thought through which units of activity and standards of achievement in those units are appropriate for progression to particular employments and courses rather than using headline grades and tariff scores. Such an approach would provide a useful language in which end users could communicate their requirements to students and those advising them, and assist in an informed personalisation of each student's learning. It should also provide a recognised currency for qualifications which are not full AS- or A-levels.

An adapted version of the Baccalaureate would be available for those on apprenticeships and training; this would ensure that theoretical understanding and basic education were provided to complement workplace experience and enable career progression and development.

CONCLUSION

Although further development work would be required, ACME believes that its recommendation of establishing clear pathways for mathematics post-16 – and framing them within an over-arching baccalaureate-style qualification – should form part of the forthcoming review of 14-19 qualifications. ACME believes that all students should study mathematics post-16, and the pathways that have been set out will allow students to do so at a level and volume that is appropriate for their mathematical needs.



The Advisory Committee on Mathematics Education (ACME) was established in January 2002 by the Royal Society and the Joint Mathematical Council of the UK. It is an independent standing committee, with members of its secretariat based at the Royal Society, and it aims to provide national policy advice in England on matters of mathematics education.

The purpose of setting up ACME was to put in place an effective and constructive partnership between policy makers and the mathematics community. One of ACME's main aims has been to inform and advise the work of policy makers – particularly the Department for Education (DfE) and the Department for Business, Innovation and Skills (BIS) – in order to assist in the drive to raise standards and promote mathematics at all levels within education in England. ACME is reactive to policy announcements, and provides constructive comments in an informal way, but the onus is also on the committee to be proactive in setting out positions on issues of current and future policy interest.

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