Report from the expert panel on core mathematics

A report from the expert panel on core mathematics to the Department for Education

October 2013

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Foreword

Mathematics is increasingly important for employment, in higher education and for making sense of the increasingly data-rich and technical world in which we live. The Advisory Committee on Mathematics Education (ACME) has estimated that each year at least 250,000 students in England with a C or above in GCSE Mathematics choose not to study, formally at least, any mathematics after the age of 16.[1] However, there is wide consensus amongst politicians, employers, higher education tutors and teachers that the majority of students in England should continue to study mathematics post-16.

Creating new mathematics qualifications that are distinctive and valued is one way of increasing the participation rate of those studying mathematics beyond GCSE. New qualifications could provide a curriculum that is better matched to the purpose of supporting those students who would otherwise not study mathematics but will need to understand and use mathematics in their further study, work and future lives.

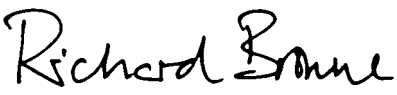
The Department for Education asked ACME to convene a panel of experts to develop guidelines on core mathematics qualifications. The Department for Education will use the guidelines to inform its decisions about which qualifications are to be counted as Core Mathematics qualifications in performance measures.

ACME extended an invitation to members of the mathematics education community to be part of the expert panel. Those chosen possess a wide range of expertise. They understand the value in studying mathematics post-16 and are committed to ensuring that opportunities are made available to provide students with recognised and structured programmes of study in mathematics.

The expert panel has reflected upon the need for qualifications that will motivate students to continue to engage with mathematics, and will also provide them with mathematical understanding and skills to support their further study and work. In this report, essential elements, such as purposes and aims of the qualification, as well as content and assessment are explored.

New qualifications will have to be of significant value to students. They should also ensure that students have a clear understanding of what they are doing when they work mathematically. To develop and consolidate understanding of mathematics and increase motivation and engagement, these qualifications must emphasise using mathematics to investigate, analyse and solve problems in realistic and meaningful contexts.

Developing new qualifications is only one part of the shift that is needed to increase participation in mathematics post-16. Government, schools and colleges, higher education institutions, and business and industry must all recognise and foster the changes that are needed. Significant investment in teacher capacity is also required, both in teachers' professional development and, in view of the very substantial potential take up of the new qualifications, in the recruitment of new teachers.



Richard Browne
Chair of the expert panel on core mathematics
7 October 2013

1 Advisory Committee on Mathematics Education (ACME) (2012), 'Post-16 Mathematics: A strategy for improving provision and participation', http://www.acme-uk.org/media/10520/20121217acme_post_16_strategy.pdf.

Expert panel on core mathematics

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Terms of reference

ACME was invited by the Department for Education to convene an expert panel, which was tasked with developing guidelines on core mathematics qualifications. The remit of the panel was to draft clear guidelines to inform the development of new Level 3 mathematics qualifications and for use by the Department for Education in deciding which qualifications may be counted as Core Mathematics qualifications in performance measures.

1. Introduction

In this report, the expert panel on core mathematics will provide clear guidelines to

- inform the development of new Level 3 mathematics qualifications
- be used by the Department for Education in deciding which qualifications may be counted as Core Mathematics qualifications in performance measures.

The report sets out the principles that the expert panel believes should underpin the design of qualifications to meet the requirements of core mathematics qualifications. It does this by first providing guidelines on the purposes, size, aims and learning outcomes that should be expected. The expert panel has then specified subject content for core mathematics qualifications. As core mathematics qualifications should ensure that students use mathematics to model real situations and solve problems, the expert panel explains what it understands by 'problem solving' and what this means for core mathematics qualifications. The panel has also emphasised that content should be taught in a way which ensures that connections are made across content areas and uses technology reflectively and strategically. Assessment objectives, a scheme of assessment and a suggested grading structure are set out, which would ensure the fulfilment of the learning objectives. Finally, the expert panel has set out ways in which new mathematics qualifications will need to be supported if they are to fulfil their purpose and equip students with mathematical skills for further study or work.

2. Purpose of core mathematics qualifications

New mathematics qualifications[2] should provide a recognised and valued path for students to gain a Level 3 qualification in mathematics. They should be clearly distinct from, and complementary to, AS and A level Mathematics, and be motivating for students for whom the current GCE qualifications are not the right choice at 16.

Core mathematics courses should provide for students who are at different starting points and who have a range of goals in terms of educational or employment progression. Therefore core mathematics qualifications should offer preparation for tackling the many and varied mathematical problems students will encounter in A level or vocational studies, in higher education, in employment, and in their lives as citizens.

Core mathematics should give students the opportunity to develop and use the mathematical knowledge, skills and understanding they have gained in previous study and to engage critically with mathematics by developing problem solving skills in realistic contexts. These contexts should be motivated by students' interests and aspirations for further study or employment. Core mathematics qualifications should build on prior learning to provide the progression required for employment or further study. The qualifications should enable students to encounter authentic data, which they analyse and investigate, with the support of modern technology where appropriate. Qualifications should be designed by awarding organisations so that teachers can make connections to other courses of study.

These qualifications should provide for students intending to follow various routes into higher education, vocational training or business and industry. For example, they could provide a grounding for students entering higher education, in subjects such as geography, history or biology, for those choosing vocational training, for example in construction, leisure and tourism or hospitality and catering, for those undertaking teaching qualifications, or for those planning to do apprenticeships, such as in the manufacturing industry.

2 The qualifications that are referred to throughout this report are called 'core mathematics' qualifications. However, it is understood that this name could change. Thus, when 'core mathematics' is used, it is referring to a category of Level 3 post-16 qualifications (either a suite of qualifications or a single qualification) which are designed for those with a GCSE at grade C or above and which allow students to engage critically with mathematics by developing problem solving skills in a broad range of realistic situations.

3. Size of core mathematics qualifications

To sit alongside a current typical post-16 programme of qualifications, and be distinct from AS Mathematics and not in competition with it, the expert panel recommends that core mathematics qualifications should be designed to be taken over two years. The qualifications should be designed to require two-thirds of the teaching time needed for an AS level qualification. Such a low-volume course would be most easily resourced and timetabled.

4. Subject aims in core mathematics qualifications

Core mathematics qualifications should aim to develop students' mathematical competence, confidence and fluency. Students should draw on but also extend the mathematical knowledge, skills and understanding they acquired from GCSE Mathematics, and should learn to apply this knowledge in order to analyse and solve challenging problems which would lead to a Level 3 qualification in core mathematics. New mathematics qualifications should aim to build a student's confidence in using mathematical thinking to address a broad range of realistic problems. In doing so, students should recognise and adopt common problem solving skills and strategies and become confident in applying mathematics in new and varied situations and contexts. The qualifications should aim to develop students' fluency in using mathematics so that they can switch seamlessly from verbal to mathematical formulations when these are needed.

Students will have different prior attainment. So too will they have different aspirations for further study and employment. The challenge is to make core mathematics qualifications attractive and engaging for a wide range of students. To this end, awarding organisations and teachers should aim to ensure that core mathematics students make connections between their wider study programme and core mathematics.

5. Learning outcomes

Many post-16 students do not yet have the technical skills to solve problems mathematically, may feel insecure in using mathematics and have difficulty in approaching problems, whether expressed in mathematical or in textual forms. It is important, therefore, that new mathematics qualifications should be designed to give students a thorough grounding in applying mathematics. This should be achieved by consolidating learning from GCSE Mathematics, increasing students' confidence in applying aspects of the GCSE Mathematics course, as well as developing new knowledge and skills in applying additional topics, examined in the context of problem solving.

Core mathematics qualifications should be designed to give students a thorough grounding in mathematics. This will be achieved by consolidating learning from GCSE Mathematics and increasing students' confidence in applying aspects of the GCSE Mathematics course, as well as additional topics, in the context of problem solving.

Qualifications must set out how they will ensure that a student develops basic competence in mathematics, but also develops both confidence and fluency in mathematics. The expert panel understands the meaning of 'competence', 'confidence' and 'fluency' to be:

- **Competence:**
  having the technical skills to solve problems mathematically
- **Confidence:**
  having the necessary understanding to feel secure in using mathematics and exploring its uses
- **Fluency:**
  having the facility to move freely between verbal and mathematical formulations of a situation

Through taking a course of study leading to core mathematics qualifications, students will:

- show competence and sound technical skills in routine applications
- gain confidence and a positive attitude towards mathematics
- learn to make sense of a situation in terms of its underlying mathematical structure
- know when and how to simplify a situation to allow it to be explored using mathematics, and when abstractions and generalisations can be made
- be able to select appropriate mathematical tools to tackle a problem in a strategic way, persevere to a justifiable solution, and effectively communicate outcomes in context
- understand the collection, processing and representation of data; be able to draw sound conclusions from data
- understand and recognise assumptions in a model and limitations in data
- understand estimation, errors and approximation; recognise their impact on the accuracy of a mathematical solution
- be able to develop a brief and cogent argument in support of conclusions they come to based on their mathematical analysis of a situation
- understand and use mathematics fluently and effectively in developing and using arguments
- move freely between verbal, graphical, diagrammatic and mathematical formulations of a situation.

6. Subject content

New mathematics qualifications should emphasise the use of mathematics to model real situations and to solve problems. In consequence, such qualifications should place limited emphasis on learning specific mathematical techniques. Such learning should not greatly exceed one-third of the content of core mathematics qualifications. This should be reflected in the proportion of the assessment credit that is allocated to assessing such learning.

The expert panel recommends that core mathematics qualifications are based on the common content outlined below. This is set out in five parts. First, the expert panel indicates the relationship between core mathematics qualifications and the mathematical techniques required in GCSE and AS Mathematics. Secondly the expert panel sets out the expected scope of study in core mathematics qualifications. The expert panel then emphasises the importance in core mathematics qualifications of appropriate emphasis being placed on problem solving, on using technology and on making connections in mathematics.

The content of core mathematics qualifications should contain a very limited number of the mathematical techniques found in existing Level 3 mathematics qualifications. Core mathematics qualifications must, however, be of Level 3 standard, and this standard is to be provided by the rigour that is required in relation to problem solving, making connections in mathematics, and use of technology.

(i) Core mathematics qualifications and other qualification content

Core mathematics qualifications should be Level 3 qualifications, and should be designed for students who have already achieved at least Level 2 in GCSE Mathematics. Core mathematics qualifications should prepare students for further study, and for using mathematics in employment and everyday life.

The expert panel recommends that the content from:

- the Foundation Tier[3] of GCSE Mathematics may be regarded as assumed knowledge
- Higher Tier of GCSE Mathematics is used freely in core mathematics qualifications, though such material should be set out in the specification as part of the content that is to be covered by the course leading to the qualification
- AS or A level Mathematics should be introduced sparingly in core mathematics qualifications.

3 This description may need to be reviewed following the introduction of reformed GCSEs in 2015.

(ii) Scope of study

The expert panel recommends that for a qualification to be certificated as core mathematics students should be expected to demonstrate fluency in applying mathematics to solve a range of different problems. In doing so they should draw on mathematical content that includes number, algebra, probability and statistics. Students should be expected to know, or be able to estimate, a range of quantities in use in everyday life. The panel considers that all students should have experience of problem solving across these different content areas to develop the flexibility of mathematical thinking that they will need in the variety of contexts they will meet as learners, workers and citizens.

The expert panel r**ecommends the indicative content set out in the table below.**

Awarding organisations may wish to submit specifications with additional content and should show how the content they include supports the purpose and learning outcomes of core mathematics qualifications.

Number	Understanding of how to work with very large and very small numbers, including using standard form Approximation and sources of error Orders of magnitude, rough estimates of products, quotients and square roots Powers of 2 and 10, elementary arithmetic understanding of base-10 logarithms and use of logarithmic scales
Algebra	Understanding graphical and algebraic representations of relationships between quantities Units and dimensions Exponential growth and decay Scaling and powers
Probability	Understanding probability, conditional probability, expectation, risk (absolute and relative) Alternative representations including natural frequencies Rough assessment of probabilities using historical or experimental data Interpretation of random phenomena, games of chance, and risk statements
Statistics	Understanding the concept of natural variation Understanding of how statistical distributions arise Measures of central tendency and variability Idea of testing a hypothesis by comparing observation with a predicted distribution Critical appraisal of numerical evidence in terms of bias, selection, framing and presentation

Other content from AS or A level Mathematics, including calculus, should not normally be included.

Awarding organisations are encouraged to submit specifications that cover such content together with additional content that they judge adds to coherence in programmes of study. In their design of specifications they should show clearly how the content they include supports the purpose and learning outcomes of core mathematics qualifications. The expert panel recognises that awarding organisations will wish to design new qualifications in ways that meet these criteria. It encourages them to draw on their expertise to do this in innovative ways that will best meet the needs of students. Awarding organisations may also wish to develop existing qualifications in ways that meet the criteria for core mathematics.

(iii) Problem solving in core mathematics

Core mathematics qualifications should be designed to ensure that students can use and understand mathematics to model real situations and solve problems. During a core mathematics course, students should use their general and mathematical knowledge and skills in a broad range of realistic situations. The expert panel considers realistic situations to be those that these arise in contexts outside of the world of mathematics and are such that someone as a student, as an employee or as a citizen would recognise as authentic and meaningful.

Problems

Problems encountered during this course should be:

- sufficiently challenging to demonstrate the Level 3 demand of the course
- purposely varied, so that students are able to identify and apply underlying mathematics and translate the knowledge and skills to new contexts
- posed in ways that require students to make and justify decisions, and articulate arguments, on the basis of their mathematical understanding
- chosen to be appropriate for investigation and solution using the mathematical content of the course.

The contexts within which tasks are set should be as realistic as possible and use authentic resource materials. Students should be encouraged to access data, generate data, and question the misuse of data and statistics.

Typical authentic materials could include:

- National and international databases (e.g. Office for National Statistics (ONS), NHS, OECD, PISA)
- Publicly available reports
- Media coverage, including blogs
- Promotional and marketing materials.

Realistic contexts might include:

- public and personal finance; demographic information; aptitude and psychometric tests; science; business analysis; medicine and healthcare; manufacturing industry; energy and the environment; construction; leisure and tourism; public policy and politics; opinion polls; human resources.

Especially in internal assessment, realistic contexts should be chosen to support other components of the student's programme of academic or vocational study or employment plans.

Solving

In completing an assessment task for a core mathematics qualification, students should:

- identify the quantifiable aspects of the information they are given
- make reasonable assumptions about quantifiable information that remains unknown
- represent situations mathematically
- use a variety of representations including diagrams, graphs, spreadsheets and algebra to formulate and explore mathematical models and to display data and results
- select and use mathematical tools effectively to analyse the problem
- interpret and evaluate their mathematical solution in terms of the original context
- communicate their findings clearly and effectively.

(iv) Making connections

In core mathematics courses, links should be made between mathematics explored in different contexts or situations. Core mathematics qualifications seek to develop problem solving skills, including how to approach a problem and make sense of a situation. In improving these skills, students should become aware of the interconnectivity of mathematical ideas across the subject content of core mathematics.

The fundamental aim of core mathematics is that students develop mathematical competence, confidence and fluency in order to analyse and solve challenging problems. Courses should therefore focus on recognising, developing and improving problem solving skills and strategies that are commonly used when problems arise in a variety of contexts requiring mathematics, drawing upon the domains of number, algebra, probability and statistics. For example, students should come to recognise that in solving problems and developing mathematical models, simplifying assumptions need to be made, so that the problem can be tackled with mathematics they know; they should come to recognise the value of looking at simple or extreme cases when trying to make sense of the situation or their own proposed solution.

In developing qualifications, awarding organisations should consider how they can best support students (and their teachers) in making connections between core mathematics, their wider study programme and everyday life.

(v) Using technology

Core mathematics qualifications should ensure that a significant element of the content can be taught and learnt through the use of appropriate technology.

Using technology in the classroom should enable students to develop skills that can be used in further education or in the workplace. Technological tools can enable students to explore large data sets, to investigate and simulate a range of problems, and provide insight into mathematical processes.

A range of existing digital tools and applications should be used by students taking core mathematics courses, including spreadsheets, graphics packages and data handling software.

In teaching core mathematics qualifications, technology should be used strategically and reflectively. Technology should enable mathematical learning, aid conceptual understanding and promote the development of problem solving skills. Students should not be taught how to use technology, but rather should understand how technology is a tool for developing mathematical understanding. Rather than using technology as a black box, it should be used in a way which allows learners of mathematics to understand the problems that they are solving and appreciate generality and structure that can be applied in future problems.

7. Assessment Objectives

Core mathematics specifications should be expected to have three assessment objectives.

- The first assessment objective should be focused upon the selection, recall and use of mathematical knowledge and techniques. The expected use of knowledge and techniques in this assessment objective is in routine applications. The assessment objective credit should be focused mainly in the external assessment component.
- The second assessment objective should emphasise problem solving and mathematical modelling. As explained below, this would be best assessed through internal assessment or innovative use of external assessment.
- The third assessment objective should place emphasis upon students' interpretation and communication of mathematics. This would also be best assessed through internal assessment or innovative use of external assessment.

The expert panel recommends that the first assessment objective is allocated a weighting of between 25 and 35 per cent of the assessment credit, the second between 40 and 50 per cent, and the third between 25 and 35 per cent.

8. Scheme of Assessment

The assessment should be set in realistic contexts, using, where possible, authentic resource materials.

The expert panel recommends that core mathematics qualifications should have 50 per cent internal assessment and 50 per cent external assessment.

(i) Internal assessment

In order to ensure that the learning outcomes of core mathematics are achieved, the scheme of assessment should recognise the need to have a balance between internal and external assessment. To ensure that the outlined assessment objectives are achieved, more innovative assessment than timed written papers is required. The expert panel recommends that 50 per cent of the assessment credit in core mathematics qualifications should be for internal assessment. In order to assess problem solving and modelling skills, as well as the interpretation and communication of mathematics, internal assessment is required.

Providing the tasks assessed are substantial in size, internal assessment will increase reliability by increasing the proportion of the content that is covered by the assessment, as compared to external assessment.

ACME's parsimony principle[4] suggests that core mathematics qualifications should be appropriate for students whatever their other academic or vocational interests, as this will make implementation possible, particularly in smaller schools and colleges. Only internal assessment will permit a sufficiently wide range of contexts to be used to meet the needs of the whole cohort of students. Students working towards A levels including those intending to move to higher education, and others doing vocational courses will be required to carry out more in-depth and longer-term engagement with mathematics through coursework.

Internal assessment might include teacher records of skills shown during the course, a portfolio of candidates' work, or extended case studies or projects. Such modes of assessment will enable students to work over an extended period.

4 ACME (2012), Post-16 Mathematics: A strategy for improving provision and participation, http://www.acme-uk.org/media/10520/20121217acme_post_16_strategy.pdf.

Working over an extended period, students would be most likely to develop competence, confidence and fluency by:

- developing general and mathematical knowledge and skills in a broad range of realistic situations, with relevance to his or her course of study or future employment
- learning how to select appropriate tools to tackle a problem in a strategic way, persevere to a justifiable solution, and communicate outcomes effectively in practice.
- being given time and space to allow for reflection, creative thinking, research, planning (for example to collect and use data), opportunities to try approaches that may turn out to be unhelpful in solving a problem.

An assessment component focused on the ability to think through problems and communicate results in verbal and graphical forms and to develop competence, confidence and fluency in mathematics will be valued by employers, higher education and vocational providers.

The expert panel acknowledges that internal assessment can have the disadvantage that it places an additional burden on teachers. Awarding organisations should be encouraged to explore ways in which this burden might be reduced through innovative forms of assessment.

(ii) External assessment

The external assessment component of core mathematics will need careful development and innovative forms of external assessment should be explored in order to ensure that the assessment objectives, particularly the second and third, are fulfilled.

Awarding organisations have exceptional expertise in assessing through timed written examinations what candidates know, understand and can do. However, the brief duration of such examinations presents challenges for the assessment of the kinds of knowledge, skills and understanding that are the essential heart of core mathematics, in particular the ability to solve substantial problems in contexts. Awarding organisations have less experience of the use, in mathematics, of the kinds of external assessment papers that will be most effective and new approaches may need to be developed.

External assessment is required to provide validity as well as the reliability that is its hallmark. To support the validity of the external assessment of core mathematics, the expert panel recommends that awarding organisations seek out information on the range of authentic contexts that could be used in these assessments. In the expert panel's view, mathematicians and users of mathematics in higher education and industry would be able to supply details of suitable contexts that could be used in core mathematics assessments and to assist in their development as course materials.

Questions posed in external assessment should require extended answers. The expert panel would welcome awarding organisations exploring the use of pre-release materials, whereby students receive information on the contexts for assessment problems in advance of the examination. Other innovative types of external assessment could be developed to ensure students' problem solving skills and interpretation and communication skills in mathematics can be developed.

Teachers will welcome sample assessment materials for core mathematics, and the volume of these should be greater than usual to reflect the new emphases of core mathematics qualifications.

9. Grading

The expert panel recommends that the grades awarded for core mathematics qualifications be pass, merit and distinction. This is an existing and widely recognised grading scheme. A small range of grades has a number of advantages.

- There would be a clear difference between grading of core mathematics and AS and A level qualifications, thus emphasising the different nature and purposes of core mathematics.
- The emphasis on passing in the proposed different grading structure would provide recognition that core mathematics qualifications should mainly be about encouraging the largest possible number of candidates to develop their mathematical competencies.
- Users are unlikely to find a finer system of grades more helpful, as it would be hard to establish clear meanings for a large number of outcomes.
- A different grading scale will make it less likely for higher education and employers to allocate identical meanings to core mathematics grades as to those associated with existing GCE grades.

10. Ensuring the success of core mathematics qualifications[5]

(i) Long term investment

There is widespread agreement about the need for new mathematics qualifications for post-16 students[6]. Developing new qualifications which are valued and recognised by schools and colleges, students and parents requires a sustained effort by government and awarding organisations and cannot be successful without long term investment. There needs to be stability in qualifications in order to ensure that the qualifications are valued by students as well as employers and higher education.

(ii) Core mathematics' relationship with other qualifications

The expert panel is keen not to diminish the importance of AS and A level Mathematics and Further Mathematics qualifications. Therefore, in developing a new qualification for students who have acquired a Level 2 pass in GCSE mathematics, there need to be clear messages about the benefits of different qualifications for different educational or employment routes. Core mathematics qualifications should not be used as a means of schools and colleges discouraging students from studying AS or A level Mathematics. Accountability measures should be reviewed to ensure that core mathematics qualifications cannot be used in such a way.

Core mathematics courses should normally engage students for two years so that they are continually developing their mathematical skills. However, given reform in GCE qualifications, it is not currently clear what the government's expectations are in relation to studying mathematics in Year 13 for students who have completed a qualification such as AS Mathematics in Year 12.

Clear pathways should be developed to allow students to move between core mathematics qualifications and AS/ A level qualifications, if this is something that is right for a student's learning.

(iii) Training and professional development

The emphasis on problem solving and communication will make these courses unique. The learning outcomes and assessment objectives are purposely stretching for students. Compared with many existing Level 3 courses, core mathematics courses will require a different approach to the teaching, learning and assessment of mathematics.

Teachers will therefore need support as they develop courses in schools and colleges, as they begin to teach these courses and then as they assess their students. A large-scale programme of funded, focused continuing professional development should be provided to support the implementation of core mathematics.

Given the likelihood of a significant increase in post-16 mathematics participation when core mathematics is introduced, the Department for Education needs to carry out an analysis of the numbers of teachers required to deliver core mathematics qualifications and implement measures to ensure that there is sufficient teaching capacity.

Quality resource materials such as textbooks and online materials will be required to support the new courses. The aims and learning outcomes for core mathematics courses should be reflected in any resources developed. A wide range of resources will be required in order to reflect the range of contexts in which mathematics can be used to analyse situations and provide insight and conclusions. Awarding organisations should draw on expertise from higher education and from industry and employers for materials that can be used for these examples. Resources developed should not be focused simply on preparation for assessment.

5 ACME (2012), Post-16 Mathematics: A strategy for improving provision and participation,http://www.acme-uk.org/media/10520/20121217acme_post_16_strategy.pdf.

6 ACME, 2012, 'Post-16 Mathematics: A strategy for improving provision and participation', http://www.acme-uk.org/media/10520/20121217acme_post_16_strategy.pdf. Nuffield Foundation/ Hodgen, Jeremy, R. Marks, & D. Pepper (2013), Towards universal participation in post-16 mathematics: lessons from high-performing countries,http://www.nuffieldfoundation.org/sites/default/files/files/Towards_universal_participation_in_post_16_maths_v_FINAL.pdf.

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