The Royal Academy of Engineering

Educating Engineers for the 21st Century:
The Industry View

A Commentary on a study carried out by Henley Management College for The Royal Academy of Engineering

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Part 1: The Industry View

Introduction

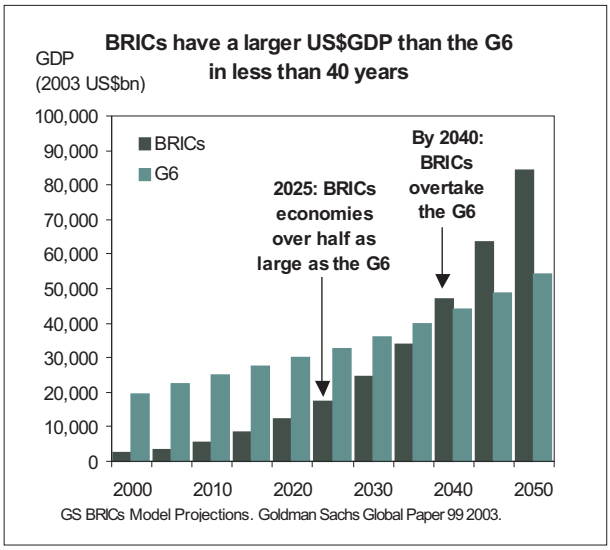
We live in a changing world, a world increasingly dependent on technology, a world where the ability to innovate and change is increasingly critical to business success.

The UK Government, in its Science and Innovation Investment Framework 2004 -2014 [1], paints a vision of the future for the UK: '…a key knowledge hub in the global economy…with a reputation…as a world-leader in turning knowledge into new products and services.' In support of this objective it sets for the UK the target of increasing R and D spend, as a proportion of GDP, from 1.9% to 2.5% by 2014.

Yet between 1994 and 2004, whilst the numbers entering university in the UK rose by almost 40%, the numbers opting for engineering degrees remained almost static, at 24,500 - dropping proportionately from 11% to less than 8% of entrants. And on graduation less than half of the engineering cohort chose to enter the engineering profession [2].

The balance of economic power is changing - the economies in the BRIC nations (Brazil, Russia, India, China) are set to overtake the G6 (US, UK, Japan, Germany, Italy, France) by 2040 [3]. Business is increasingly global.

Meanwhile, in China and India some 464,000 engineers graduate each year [4].



The roles of engineers are changing. From delivering products to integrating systems with growing technological complexity and interdependence and providing an integrated solution, or a service, to the customer. Management complexity is increasing, with globalisation and offshoring demanding effective communication and teamworking across continents, time zones and cultures. New engineering industries and disciplines are developing, such as medical engineering.

" UK-based designers have to offer considerably more value in terms of creativity and pace in order to remain competitive" " …we expect more creativity, more innovation, more excellent technical skills… that will maintain the activities in the UK… compared to the work in low cost countries…"

In the UK our education system has been changing. Shortages of maths and physics teachers are impacting on the quality of secondary education for many young people. More students now study at university, but numbers in engineering are at best static. Whilst children grow up communicating via camera phones and text messages, playing videogames and roaming the web, engineering training in universities has evolved only slowly from the experiences of their parents. Increased student mobility and global recruitment means that UK graduates and degree provision must be internationally recognised as world-class.

Against this background of threats and opportunities, The Royal Academy of Engineering decided to launch a review of university engineering education. The review is exploring the changes required to educate the engineering graduates needed by industry to deliver the challenges of the 21st Century. The membership and terms of reference of the 'Educating Engineers for the 21st Century' working party are listed in Appendix 1.

The first stage of the review has involved a major study of the perceptions and needs of industries, operating in the UK, in relation to engineering graduates now and in the future.

The Industry Study

The industry study started with 21 in-depth interviews with engineering companies. These were followed by 13 interviews with SMEs, 7 of which were high-tech spin-outs. In addition, three focus groups were held with recent graduates. The responses were used to produce a detailed questionnaire covering: changes in the industry; current and future skills requirements; the quality of engineering graduates, UK and international; changes required to engineering education.

IN-DEPTH COMPANY INTERVIEWS

ABB
Arup
Atkins
BOC Edwards
BP plc
BT group (2 interviews)
DSTL
Filtronic plc
Ford Motor Company Ltd
Foster Wheeler Energy Ltd
IBM
National Grid Transco
Nortel
Renishaw plc
Rolls-Royce plc
Shell UK
Siemens UK
Smiths Group plc
Thales UK plc
Thames Water

The questionnaire was sent out to over 8,000 companies and 444 usable responses were received, a response rate of 5.4%. 53% of the sample consisted of SMEs (less than 250 employees).

The study was carried out on behalf of The Royal Academy of Engineering by Henley Management College. A summary of the final report is presented in Appendix 2, the full report can be downloaded from the Academy's website: www.raeng.org.uk/henleyreport.

This study represents the largest collection of industry views on graduate engineers ever collected in the UK and leads to important conclusions about the importance of engineers to the success of UK industry and the changes in educational requirements to meet future challenges.

Conclusions

The Academy's Working Party and Fellows on the Standing Committee for Education and Training have identified the following major conclusions from the study of industry views.

1 Over the next 10 years there will be a worsening shortage of high calibre UK engineering graduates going into industry. This shortage will impact the productivity and creativity of UK-based businesses unless it can be addressed.

In several areas, companies in the survey report difficulties today in recruiting graduate engineers. Many companies comment that is difficult to get 'enough of the best'. Looking forward, they expect graduate engineers to make up an increasing proportion of the workforce over the next 10 years. The latter point is encouraging in the light of the aim, stated in the Science and Innovation Investment Framework [1] to raise UK R and D spending from 1.9% to 2.5% of GDP by 2014.

However, against an increasing proportion of young people entering university, numbers of entrants to engineering are static or even dropping. Companies are concerned about the 'pipeline' of suitably motivated and qualified young people in schools equipped to progress to engineering degrees.

If we are to deliver the vision of the UK as a global leader in turning knowledge into new products and services, we need a step change in the number of students entering engineering courses.

The issues need to be tackled on several fronts. Contributions to the solution will come from: increasing the numbers of students studying maths and physics at school; increasing the proportion of these students who opt to study engineering; retaining a higher proportion of engineering graduates in industry; allowing overseas students who have studied at UK universities to remain in the UK to work for a longer period than the current 1 year.

Solutions will include better maths and physics teaching in schools, effective schemes to encourage students to consider studying engineering, more inspiring engineering degree courses with closer industrial engagement and changes to legislation.

The survey identifies current shortage areas as Civil Engineering, Electrical and Electronic Engineering and Systems Engineering. Companies identify graduates in Information and Communications Technology and Materials as being key to their future growth.

2 Shortages of suitable engineering graduates and skill gaps are impacting the performance of UK businesses.

Over one third of companies responding indicated that shortages and skill deficiencies impacted on new product development and business growth, as well as on recruitment costs.

Specific gaps were identified in problem solving and application of theory to real problems, breadth and ability in maths.

3 University courses need to provide more experience in applying theoretical understanding to real problems.

Comments from senior industrialists

"One failing of universities now is that some of the theory never gets translated into reality"

" [graduates] need a more realistic view ...."

Whilst industry is generally satisfied with the engineers it recruits, we cannot afford to be complacent. The biggest concern is with the ability of graduates to apply their knowledge to real industrial problems. This is seen to have become more acute in recent years and is identified as one of the skill shortages impacting business growth.

The graduate focus groups also expressed concern about limited and 'unrealistic' project work in their degree courses. Project work was nevertheless identified as the most important element of their education in terms of their subsequent experience in industry.

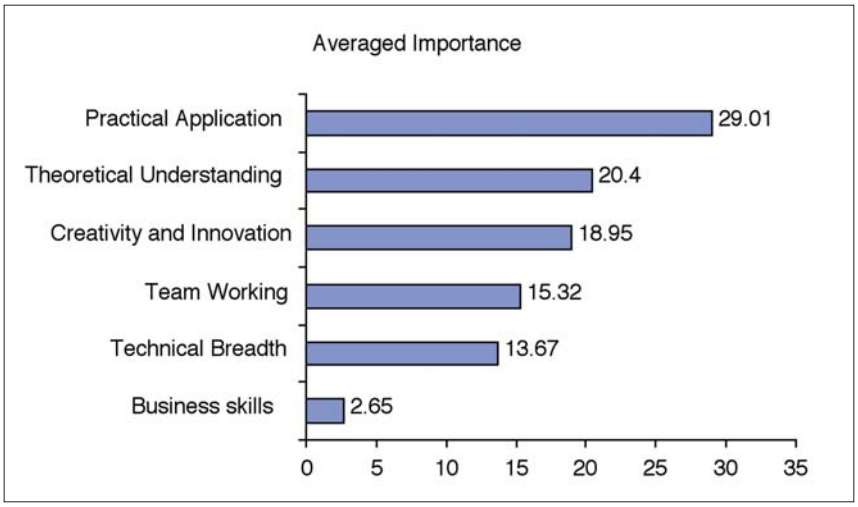
Over the past 10 years the unit of resource for teaching an engineering undergraduate has fallen by a factor of two to three [5]. This has led to a reduction in expensive practical and project work and an increased reliance on computed-based models in place of real experiments. At the same time academic staff members have been focussed on increasing their research outputs to improve performance in the Research Assessment Exercise, leaving teaching as a 'poor relation' in terms of competition for staff time and commitment in our leading universities.

4 The quality of the best UK graduates is as good as their peers in Europe, despite our shorter degree courses

Companies expressed concern over the additional costs/debts associated with the 4 year MEng, compared with a BEng. There was no evidence of a strong desire to move to 5 years in line with other parts of Europe.

It is important that we achieve 'Bologna Compliance' within the 4 year MEng structure for UK engineering degrees to ensure that both our students and courses remain highly marketable in other parts of Europe. UK universities will need Government support to ensure that further negotiations allow for this outcome, and HEFCE will need to recognise the additional cost of new elements which may be required to achieve compliance.

5 UK engineering degree courses need attention: to recognise the changing requirements of industry; to attract and maintain motivation of students; to ensure our degrees continue to be recognised in Europe.



In terms of priorities for future graduate skills, respondents present a very consistent picture. Practical application, theoretical understanding and creativity and innovation are seen as the top priorities. Whilst broader technological understanding is also important, it should not come at the expense of understanding the fundamentals.

Key business skills are envisaged primarily as commercial awareness or sensitivity – an understanding of how businesses work and the importance of the customer - combined with a basic understanding of project management.

The perspective of the graduates in the focus groups again mirrored the business respondents and emphasised what motivates students to study engineering: a good all round degree course offering a wide range of career options, a strong sense of wanting to make a difference, contributing to society and being able to see the results of your creativity: 'I did that'.

The strong focus on creativity and innovation supports the conclusions of the Cox Review [6] about the importance of creative skills in improving the UK's competitiveness in the face of the challenge from the emerging economies. The importance ascribed to creativity by those responding to the survey is an encouraging indication that business recognises Sir George Cox's challenge.

It is important that we review our engineering degree provision to ensure that we are providing education, training and challenges that address the future needs of industry, motivate students to come into engineering and stay in the profession, and that maintain the quality and standing of UK degrees and graduates with UK-based companies and our colleagues in Europe and overseas.

Closer collaboration between industry and universities in the area of undergraduate education is a key requirement going forward.

Business Skills

"… an attitude - commercial awareness, open to consumers: consumers are always right. Engineers tend to be the last people in any business to realise that …"

"I am not hugely bothered about business skills. I think as long as they have common sense they will learn the business skills pretty quickly when they come on board."

Sir George Cox,
November 2005

" The premium that will be placed on creativity in the 21st Century should give the UK a flying start in the race for competitive edge. The question is whether business will rise to the challenge of exploiting the creative capabilities at its disposal. The outcome won't just affect business itself. It will affect us all."

6 Industrial experience is a major factor in recruitment of new graduates

The importance of the ability to apply academic learning in an industrial or business environment is emphasised by the importance companies ascribe to industrial experience. A large majority of companies report using industrial experience, either before university, eg the BEST 'Year in industry' programme, or during university as vacation or sandwich placements as an important discriminator in selecting job applicants for interview.

7 Large companies and SMEs have very similar requirements for graduate education and skills

Few differences emerge between the needs of large and small companies in this survey where half of the responses were from companies employing less than 500 employees. One that can be identified is that SMEs prefer graduates with some experience of the commercial world before recruitment, whereas large companies recruit directly from universities and have their own graduate training schemes.

8 Structured graduate training schemes are needed to support SMEs

Whilst almost 90% of companies with over 500 employees report having graduate training schemes in place, more than half of the SMEs responding do not have such schemes.

There is an opportunity for organisations such as sector skills councils/professional institutions/RDAs to look at how these can be developed and delivered for groups of small businesses, or for large companies to work with SMEs in their supply chains to offer provision for graduate training and mentoring.

Project work

"… practical project work, preferably with an industrial partner is necessary"

"More creative, practical and market-led project work."

Interim Recommendations

The Working Party on Educating Engineers for the 21st Century will be continuing its work in Stage 2, consulting with universities, students and graduates about the curriculum innovations, in terms of content, style and approach, required to deliver both more high quality engineering graduates and more high quality graduates with relevant education and skills for industry. The Working Party has agreed the following 'interim' recommendations at this point in the review.

(i) Engineering courses for the 21st Century

Engineering courses must become better aligned with the changing needs of business and industry. In particular, more and better quality project work is needed, based around real-life problems, ideally delivered in collaboration with industry.

Work is needed to improve the approach to teaching to ensure students remain motivated and engaged, and graduate keen to pursue engineering careers. There are already important developments in this area, such as the pedagogic approach taken in CDIO [7], and team-based hands-on engineering

experience such as Formula Student [8] and Constructionarium [9]. Sharing of and implementation of best practice between universities needs to be encouraged by such bodies as the Academy, professional institutions and HEFCE.

Constructionarium

Formula Student

"… it is about teaching engineering as an applied science, applied business science, as opposed to teaching it as a pure science."

Developments of this sort will not only improve graduate performance in companies, but can also improve recruitment into engineering courses and student motivation.

(ii) Industry engagement with undergraduate education

Industry needs to commit to greater involvement with undergraduate engineering education if the changes it requires are to be delivered. For example: through industrial project topics, compulsory assessed vacation placements, visiting professors lecturing, leading industrial case studies, visits, advising on course content and material etc. This is particularly important in areas where there is not yet a strong engineering academic research base, such as systems engineering, design, sustainability, service and support engineering.

The Academy Visiting Professor Scheme is an example of best practice in this area which needs to be rolled-out across all departments.

(iii) The increased cost of 'hands-on' engineering training must be recognised

Industry engagement, organising placements, providing more real-life practical experiences are time consuming for academic staff and expensive to implement. Funding for revision of undergraduate engineering provision and a recognition of the increased cost of the type of education required is essential.

Additional elements of industry-based or supported project and problem-solving activities could offer an important route to ensure that UK MEng degrees remain recognised in Europe and compliant with the Bologna agreement.

Government (HEFCE) needs to increase the unit of resource for undergraduate engineering if industry is to receive the graduate workforce it needs to compete globally in the 21st Century.

(iv) Status of University Teaching

The status of teaching in universities has suffered as a result of the focus on Research Assessment Exercise performance. Initiatives are required to redress the balance and recognise the importance of excellent teaching as a key contributor to the economy and the UK's future as a global leader in innovation and technology. Current good practice includes recognition of teaching performances as a key element of the promotion case to Professor.

The new BNFL/RAEng prize for 'Innovation in Engineering Education' is a step in the right direction, but changes to the way staff are rewarded and promoted may also be required.

(v) Filling the 'Pipeline'

Current initiatives to encourage more school students to study maths and physical science to A level and the Budget announcement on mechanisms and targets to increase the number of science teachers in schools are welcomed. There may be opportunities for universities and companies to collaborate more closely with other providers, such as the schemes in the BEST programme, and these should be explored.

(vi) Creativity, technology and business teaching

Sir George Cox's recommendation [6] on creating centres of excellence in the UK combining creativity, technology and business teaching is strongly supported.

(vii) Graduate training schemes for SMEs

The provision of graduate training schemes for SMEs recruiting small numbers of graduates is an important issue. Larger companies might be able to support graduate training for SMEs in their supply chains, and this is an area where the RDAs/DAs and the professional institutions could collaborate .

The Next Stage

The next stage of the Academy review will involve testing the industry views and the recommendations and conclusions derived from them with universities and graduates. It will examine current best practice in the UK and overseas and identify additional requirements. An action plan will be developed with recommendations for universities, companies, government, professional institutions, the Academy itself and others involved in engineering. The first steps involve publication of the industry report and consultation with the academic community. To achieve the study's final objectives, the working party is being expanded to increase both academic and industry representation.

References

[1] Science & innovation investment framework 2004-2014, HM Treasury, July 2004.

[2] Engineering UK 2005, etb Research Report , November 2005.

[3] Goldman Sachs Global Economics Paper No 99: Dreaming with BRICs: The Path to 2050, October 2003.

[4] Framing the Engineering Outsourcing Debate: Placing the United States on a Level Playing Field with China and India, Duke University Master of Engineering Program Paper, December 2005.

[5] University Finances: What will the next five years bring? Presentation by Dr Jonathan Nicholls (Registrar, University of Birmingham) to the Engineering Professors' Council Congress, Brighton UK, March 2005.

[6] Cox Review of Creativity in Business: Building on the UK's Strengths, HMSO November 2005.

[7] See www.cdio.org

[8] See www.imeche.org.uk/formulastudent/.

[9] Constructionarium: Build to Learn. CEBE Transactions, Vol. 2, Issue 1, pp6-16 April 2005.

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Appendix 1: Terms of reference

- To draft an Academy policy statement on the changes required in the engineering education curriculum for the formation of the professional engineers required in the 21st Century.

- To take account of the following aspects in the study:

  The need to ensure that the UK can strengthen its position as a centre for world-class high value added engineering

  The Business and Industry Requirements with particular reference to the requirements and preferences of International Business following the Bologna Declaration.

  The nature and length of engineering degree courses with particular reference to the impact of the Bologna Declaration and the changes occurring in pre-university education.

  The process of Regulation and Accreditation.

  The most effective ways to recruit high calibre students.

  Overseas developments and best practice.

- To complete and present the study to The Standing Committee for Education and Training.

Appendix 2:

Executive Summary of the Henley Report for The Royal Academy of Engineering

Introduction

This report presents the results of a research project carried out by Henley Management College on behalf of The Royal Academy of Engineering to investigate UK undergraduate engineering education from the perspective of current and future needs of industry. The research is based on a combination of in-depth interviews with industry practitioners, focus groups with recent graduates, and a large-scale survey of firms within the industry. This extended executive summary provides an overview of key themes that emerge from the findings. For further details the reader is referred to the full report. This is available free on The Royal Academy of Engineering website at www.raeng.org.uk/henleyreport.

The Engineering Graduate Today

Newly-recruited engineering graduates are used in a wide range of roles. Whilst research and development, design and production/manufacturing are the most prevalent, engineering graduates are found across the product lifecycle and throughout the value chain. As a result many graduate engineers find themselves in roles which do not necessarily involve hands-on specialist engineering. To fill these roles engineering firms look for skills and attributes in two broad areas. Engineering technical skills: a sound knowledge of discipline-based fundamentals; a solid base of mathematical knowledge; creativity and innovation; the ability to apply theory in practice. Technical skills must be supported by enabling skills that allow the engineer to operate effectively in a commercial working environment: communication skills; team-working skills; business awareness of the commercial implications of engineering decisions.

Engineering firms use a wide range of methods to attract and develop the engineering graduate talent they need. Work placements play an important role in the recruitment process. In terms of skills development, whilst many companies offer formal graduate development programmes, the research suggests that nearly one-third of all firms have no formal scheme in place.

The Quality of Engineering Graduates

There is some evidence both of skill shortages and skill gaps in the UK graduate engineering labour market, although the picture in the latter case is rather mixed. There is also a feeling that the grade of degree awarded is no longer a consistent indicator of a candidate's actual abilities. Companies recruit engineering graduates from overseas universities both as a response to specific skill shortages and in order to support their overseas operations. Whilst the research concludes that the best UK graduates are broadly comparable globally, graduates of Continental universities are seen as especially strong in mathematics and fundamental theory. In addition, China and India now produce some very high quality engineering graduates.

The research findings indicate a tight labour market for high quality engineering graduates. In particular there are concerns in two areas. Firstly, firms report that skill deficiencies impact across their activities, increasing recruitment costs, delaying the development of new products, and restricting company growth. Secondly, there are concerns over the long-term pipeline of young talent coming into engineering from schools, onto university engineering courses and subsequently into industry.

Industry Differences

Although there is a considerable homogeneity overall in the views of the firms taking part, the research includes a closer examination of two segments of the industry in order to understand better their particular needs and experiences. The first segment is the small and medium-sized enterprise (SME) sector. SME engineering firms look for graduate engineers to have broadly similar skill sets to those sought by larger firms, although for some companies, prior work experience is seen as essential. Overall, however, the research finds no significant difference between SMEs and larger companies in satisfaction with recruitment of graduates either direct from university or after 1-2 years work experience.

The second segment is the university spin-out sector. As these businesses are set up to exploit university intellectual property (IP) their use of engineering graduates is focused very much on research and development to bring the IP to market. Whilst such firms would like to have graduates with some commercial experience, their technical capability is seen as of greater importance.

Future Skills Needs

The pace of change in the industry is expected to intensify: an increased need to focus on solving customer problems; emphasis on the service dimensions of products; a growing requirement to provide system solutions; increasing complexity of the management task; growing technological complexity and interdependence at all levels. Globalisation will continue to affect both the demand and supply-side of industry. The rapid growth of offshoring offers a real challenge which will force UK engineering to concentrate on higher-value added activities. This turbulent environment will place a premium on innovation and creativity.

Engineering firms expect an increase in the proportion of graduates in their workforces over the next ten years. Electrical/electronic and systems engineering are likely to be of increasing importance. The top priorities in terms of future skills will be practical application, theoretical understanding, creativity and innovation.

To ensure that suitably skilled engineering graduates are available in the future, there is a need to enhance courses in terms of their development of practical skills, although not at the cost of ensuring that students have a strong theoretical basis. More relevant, business-oriented project work and significant work experience in an engineering environment are two mechanisms by which it is suggested that these skills can be developed. Closer university-industry ties are seen as essential.

The Engineering Graduate in the Future

The research synthesises these findings into a picture of the graduate engineer of the future. At the heart lie the defining and enabling skills that form the core competencies of the engineering graduate. It is this particular combination of skills that marks out the engineering graduate and underpins the roles that industry will need such graduates to undertake: firstly the role of the engineer as a specialist – technical experts of world-class standing; secondly, the engineer as an integrator – operating and managing across boundaries in a complex business environment; thirdly, the engineer as a change agent – providing the creativity, innovation and leadership to shape industry for a successful future.

This vision underlines the vital importance of undergraduate engineering education to the sustainability of UK industry. At the same time it emphasises the reciprocal responsibility of industry in ensuring the future excellence of undergraduate engineering education in the UK.

The Royal Academy of Engineering

As Britain's national academy for engineering, we bring together the country's most eminent engineers from all disciplines to promote excellence in the science, art and practice of engineering. Our strategic priorities are to enhance the UK's engineering capabilities, to celebrate excellence and inspire the next generation, and to lead debate by guiding informed thinking and influencing public policy.

The Academy's work programmes are driven by three strategic priorities, each of which provides a key contribution to a strong and vibrant engineering sector and to the health and wealth of society.

Enhancing national capabilities

As a priority, we encourage, support and facilitate links between academia and industry. Through targeted national and international programmes, we enhance – and reflect abroad – the UK's performance in the application of science, technology transfer, and the promotion and exploitation of innovation. We support high quality engineering research, encourage an interdisciplinary ethos, facilitate international exchange and provide a means of determining and disseminating best practice. In particular, our activities focus on complex and multidisciplinary areas of rapid development.

Recognising excellence and inspiring the next generation

Excellence breeds excellence. We celebrate engineering excellence and use it to inspire, support and challenge tomorrow's engineering leaders. We focus our initiatives to develop excellence and, through creative and collaborative activity, we demonstrate to the young, and those who influence them, the relevance of engineering to society.

Leading debate

Using the leadership and expertise of our Fellowship, we guide informed thinking, influence public policy making, provide a forum for the mutual exchange of ideas, and pursue effective engagement with society on matters within our competence. The Academy advocates progressive, forward-looking solutions based on impartial advice and quality foundations, and works to enhance appreciation of the positive role of engineering and its contribution to the economic strength of the nation.

The Royal Academy of Engineering promotes excellence in the science, art and practice of engineering.

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