Widening Participation and its Impact: The Mathematical Background of Students from a Vocational Educational Programme

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Abstract

This paper is focussed on students entering University from a BTEC (Business & Technology Education Council, Edexcel) background. Specifically it reports the results of a Higher Futures [1] project with two main aims: (i) to better understand and summarise the student entry profile and thus (ii) to develop and provide suitable pathways to improve progression. The results are presented in a format to be of optimum use both for admissions tutors who wish to assess student suitability and for year one tutors (and maths learning support services) looking to provide appropriate and targeted support.

1. Introduction

The University of Sheffield (UoS) has known for some time that students entering an engineering programme with BTEC qualifications will, in many cases, struggle with the mathematics components. With increasing pressure to widen participation there is a need to facilitate better access and enable good progress for students with such vocational backgrounds. Two aims are obvious:

a. Understand and summarise the student entry profile and

b. Provide suitable pathways to improve progression. Critically the requirements may differ from those for A-level students who dominate the literature.

As stated in the ACME Policy Report, Mathematics in FE Colleges [2], university admissions tutors need to know whether a college student has developed the necessary mathematical skills and knowledge to cope. Moreover, often tutors know very little about the mathematics within a BTEC National Diploma (ND) in Engineering.

Students enter full-time BTEC ND engineering programmes for a variety of reasons: a FE environment is more receptive for them than school; the broader mix of academic and vocational learning has a greater appeal than A-levels; links with industry through the college may lead to an apprenticeship or local employment. The qualification is a strong brand, and students will qualify with a broad range of knowledge from the qualification itself, practical skills due the nature of the vocational approach and, quite often, experience from a work-placement making them a worthy proposition for any employer. However, there are those who subsequently wish to consider the move to university, because although they did not originally believe they had the academic ability, this ability developed as their ND course progressed. With the government encouraging universities to take students from a wider range of non-traditional qualifications, and universities inviting applications from BTEC students, this should be a reasonable option.

Thus UoS used its Higher Futures [add a reference] funding to focus on mathematical barriers to admission and progress by appointing a fixed term Maths Development Officer to liaise with admissions tutors and local colleges, to develop sustainable and beneficial links, make sustainable proposals for tackling the key aims and also to find ways of raising the
profile of maths options within FE colleges. This paper gives evidence for the important conclusions so far:

a. The assessment strategies common within BTEC methodology often contribute to the ill-preparedness of students for study in HE.

b. BTEC students have low confidence levels in mathematics and often significant gaps in both skills and knowledge.

Section 2 gives more detail on the mathematics with BTEC and its assessment, section 3 presents the results of a survey of local FE colleges, section 4 gives some proposals for action and is followed by conclusions.

2. Qualification Structure and Assessment Strategy

A National Diploma usually takes 2 years. It consists of a group of core units and then optional units from one or two further groups to make up the total number of units required. Details of each qualification can be found on the Edexcel website [3]. Engineering courses include Mechanical, Aerospace, Electrical and Manufacturing, amongst others. Each unit on the programme is graded Pass, Merit or Distinction, a number of points awarded against each grade resulting in an overall aggregate score. This score is converted into an overall grade, for example Distinction-Distinction-Merit (DDM), which equates to A-level grades A, A, C. However, while this overview seems straightforward, it conceals two major differences between diplomas and A-levels which are of concern to Universities.

First, the structure of qualification will often meet local employer needs, so it is possible for students from two different colleges to both have a National Diploma in Electrical Engineering at DMM and yet up to 50% of the units they took could be different. It is this unit option profile which could contribute to possible shortfalls in the mathematics component and hence ill-preparedness for university study on engineering programmes.

The second area of concern is the inconsistency in the assessment strategies adopted. Each BTEC specification gives clear guidelines as to appropriate assessment strategies, correctly guiding centres to assess students in a way that meets learner needs, within the structure of college delivery of that programme. Without elaborating here, and using extremes to make the point, in one college a student could be assessed by unseen exams for all of their studies, but another college may ask students to complete assignments over a period of time, submitted by a set deadline. In practice, it will probably be a mix of these assessment instruments. However, if a university uses a high proportion of assessment by unseen exams, students without exam experience will be disadvantaged, even though their qualifications and grade profile are equivalent to their peers\(^1\). (University admissions tutors can visit the Edexcel website or seek advice from a local FE institution to gain further knowledge on unit profile, content and assessment methods.)

A final issue of obvious potential concern is the actual mathematics content. On BTEC engineering programmes there are two specific maths units: the core ‘Mathematics for Technicians’ and the optional ‘Further Mathematics for Technicians’. Some of the other units have a mathematical content in them i.e. ‘Mechanical Principles and Applications’, but as indicated above, these units may or may not form part of the qualification profile. It is likely that universities will ask for students to have studied the Further Maths unit and

\(^1\) University admissions tutors can visit the Edexcel website or seek advice from a local FE institution to gain further knowledge on unit profile, content and assessment methods.
achieved at least a merit in this subject. For most of its engineering programmes, UoS requires a distinction in this subject. Critically, this unit is not to be confused with Further Mathematics taken at AS/A2-level and, as discussed in the next section, has far less content both in depth and breadth.

3. Survey of student mathematical confidence in local colleges

Part of the Higher Futures initiative is to develop stronger links with, and progression routes from, local colleges. A logical first step was to identify the areas of greatest need and thus to carry out a survey of student confidence levels, in maths, of those students on BTEC engineering programmes in the region. The results will help inform support mechanisms at the university and guide any initiatives aimed at improving student mathematical skills.

With the kind permission of the engineering departments at local colleges, a questionnaire was distributed to their students and returns from eleven groups across six colleges were received. An overview of the questionnaire and process is as follows:

a. Students in their second year of either a National Diploma or National Certificate, or on the first year of the Higher National Certificate/Diploma (HNC/D) were surveyed as they should, by now, have experience and/or knowledge of the key mathematical topics (in essence the contents of the Maths for Technicians unit, i.e. Algebra, Statistics, Mensuration, Trigonometry and Calculus).

b. For each topic, students were asked to score their confidence level on a scale of 1 to 5, 1 being low confidence and 5 being high confidence.

c. A group mean score was collated for each individual topic.

The authors accept that there are limitations with this style of questionnaire as well as the quantity of data and thus this area requires further work, but nevertheless believe there is sufficient data to give useful insights. Table 1 summarises the topic mean scores (a topic score may be the average of questions on several sub-topics) for the 11 groups surveyed:

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>STUDENT GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>ALGEBRA</td>
<td>3.22</td>
</tr>
<tr>
<td>STATISTICS</td>
<td>4.13</td>
</tr>
<tr>
<td>MENSURATION</td>
<td>4.00</td>
</tr>
<tr>
<td>TRIGONOMETRY</td>
<td>3.29</td>
</tr>
<tr>
<td>CALCULUS</td>
<td>2.96</td>
</tr>
<tr>
<td>RESPONSES/OUT OF*</td>
<td>8 out of 10</td>
</tr>
</tbody>
</table>

*Number of questionnaires completed out of number of students enrolled on course; ** Not given

Looking at the scores for Statistics and Mensuration, with only two scores below 3.0, it could be argued that we have no real concerns here, though examination of the content and criteria for both suggests they are not too demanding. Groups 2, 3, 6 and 11 have a low mean score in all three of Algebra, Trigonometry and Calculus. In Calculus, there are six groups with a mean score below 2.5, and only one with a score greater than 3.0.

To try and identify any particular topic weaknesses across all groups, it seemed reasonable to highlight which individual sub-topics had a mean score well below the overall topic mean
score. For instance, group 8 had an overall mean for Algebra of 3.35, but an individual mean of 3.0 for solving problems using the laws of logarithms. These are considered good mean scores, but within this particular group, using logarithms was a relative weakness.

Only considering the topics of Algebra, Trigonometry and Calculus, table 2 details the number of low individual sub-topic mean scores relative to the overall mean score in all 11 groups:

Table 2 Sub-topics with Mean Scores below Group Mean Scores

<table>
<thead>
<tr>
<th>Algebra Topics</th>
<th>Number out of 11 below group mean</th>
<th>Calculus Topics</th>
<th>Number out of 11 below group mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transposition of formulae</td>
<td>0</td>
<td>Differentiation of simple polynomials</td>
<td>6</td>
</tr>
<tr>
<td>Laws of indices</td>
<td>6</td>
<td>Differentiation of simple trigonometric functions</td>
<td>0</td>
</tr>
<tr>
<td>Laws of logarithms</td>
<td>11</td>
<td>Differentiation of simple exponential functions</td>
<td>2</td>
</tr>
<tr>
<td>Solving linear equations</td>
<td>2</td>
<td>Evaluate gradient at a point</td>
<td>2</td>
</tr>
<tr>
<td>Y = mx + c (equation of a straight line)</td>
<td>2</td>
<td>Integration of simple polynomials</td>
<td>8</td>
</tr>
<tr>
<td>Solving simultaneous linear equations algebraically</td>
<td>5</td>
<td>Integration of simple trigonometric functions</td>
<td>5</td>
</tr>
<tr>
<td>Factorise linear equations</td>
<td>6</td>
<td>Integration of simple exponential functions</td>
<td>7</td>
</tr>
<tr>
<td>Factorise quadratic equations</td>
<td>4</td>
<td>Find the constant of integration</td>
<td>9</td>
</tr>
<tr>
<td>Solve quadratic equations using formula</td>
<td>3</td>
<td>Definite integration</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area under a curve (quadratic function only)</td>
<td>6</td>
</tr>
<tr>
<td><strong>Trigonometry Topics</strong></td>
<td></td>
<td><strong>Trigonometry Topics (cont)</strong></td>
<td></td>
</tr>
<tr>
<td>Trigonometric ratios sine, cosine and tangent</td>
<td>0</td>
<td>Phasor sum of two waveforms</td>
<td>10</td>
</tr>
<tr>
<td>Sine and cosine waveforms over one cycle</td>
<td>2</td>
<td>Conversion between degrees and radians</td>
<td>1</td>
</tr>
<tr>
<td>Sine and cosine rules</td>
<td>1</td>
<td>Find areas and arc-lengths using radians</td>
<td>9</td>
</tr>
</tbody>
</table>

3.1 Discussion of survey results

The table shows that for solving problems using the laws of logarithms, all 11 groups had a mean score below their group mean score. However, only 2 groups indicated that, relative to the group mean score, problems involving sine and cosine waveforms were a weakness.

For those sub-topics where a score of 6 or more in the above table is given, colleagues suggest that some of these are, through their experience, areas of concern for any engineering student weak in maths, whether they come from a BTEC background or not. However, this table does present some anomalies; why is factorising linear equations less problematic than factorising quadratic equations; if differentiation and integration of simple polynomials is a challenge, there is not much chance of progressing any further, one would
have thought; and if dealing with sine and cosine rules is no real challenge, why is the phasor sum of two waveforms apparently difficult?

As alluded to already, selecting a sample of students from each of these groups and obtaining some qualitative data could provide a correcting factor on some scores, so results could change in either direction. For instance, if a student did not recognise what the term ‘polynomial’ meant, but could differentiate simple power terms when presented with this change of language, there would be a better mean score for this subject and fewer groups showing it as a relative weakness.

But what are the possible reasons for these scores? If students do not understand the language of maths and the correct use of notation, they are not likely to engage with the subject, so they will respond inappropriately to such questionnaires.

3.2 Discussion of underlying causes

There may be a number of underlying causes for the relatively low confidence of BTEC students as summarised in this section. These can be paraphrased as time, assessment and breadth/depth.

Within a BTEC ND, a typical maths lesson for either Maths or Further Maths will be 1.5 hours in length, one lesson per week, providing approximately 54 guided learning hours (GLH) over the year. Provided other units with a strong mathematical content are also part of the ND programme, this may not be problematic. However, the GLH does not compare favourably with the traditional A-level maths student who could receive between 4-5 hours of maths lessons per week (more than 120 annual GLH). With such a limited amount of contact time it is clearly questionable as to whether students receive ample, guided, opportunities to practice the skills required. Even if directed to invest more of their own time into improving their mathematical skills this may not sit well with the loading of their other modules.

Parallel issues are the types of assessment that are common in FE colleges. Does the assessment strategy adopted help develop individuals, or encourage mediocrity? Does a poor average group performance lead to better performing students receiving less input across the range and depth of topics than if they were with stronger peers? Also, as discussed in section 2, the assessments themselves may not build confidence in exam scenarios.

Finally, the content of both Maths and Further Maths units, in terms of the topics addressed, not only represents just 50-60% of the pure maths topics taken at A-level, but also, in the time allowed, is unable to address the depth expected of an A-level student. Thus it is essential that BTEC students wishing to progress from a BTEC engineering programme to be successful at university are able to (and encouraged to) select other units that have a strong, perhaps related, mathematical content.

4. Student Support and Future Plans

It is a perhaps an obvious statement that BTEC students who wish to attend university are likely to be the best performers on their programme, achieving distinctions in maths and having the appropriate unit profile. Universities must recognise that such students have a lot to offer regarding their personal organisation, study skills, possible work experience and the broader range of subjects they will have studied. The fact they now have a desire towards a more academic route compared to when they started their BTEC course indicates they are of the correct mind-set to want to be successful. Hence, despite being under-prepared mathematically, this does not mean they cannot progress quickly given the right support and
environment. A student who recently progressed from the university foundation year to an engineering programme stated the extra support he received from MASH (see next paragraph) gave him so much confidence he considered he no longer needed his notes and could rely upon the mathematical formulae sheets. This exemplifies how effective, appropriate, targeted support can be.

The UoS has recently established their own Maths and Statistics Help centre (MASH) [4], where all students can drop-in to receive targeted help as appropriate. MASH has also developed diagnostics to be taken by students to help inform them of their strengths and weaknesses; the MASH web-pages have a range of study materials for anyone to use and links to other maths supportive sites. These all supplement whatever structures and resources engineering departments already have.

Nevertheless, it is recognised that BTEC students may have specific or additional needs and thus, as part of the Higher Futures initiative, stronger links are being developed between UoS, Sheffield Hallam University and regional colleges to consider what these needs might be and how best to address them. Some ideas under consideration are:

a. Additional lessons for ex-BTEC students tailored to their needs and to complement existing departmental arrangements.

b. Funding FE college staff to be released from their timetables to develop resources for maths, the intention being for them to share new resources across the network, enhances the maths skills of BTEC students, raise the confidence levels and the grade profile and hence raise student aspirations.

5. Conclusion

Widening participation is government policy and hence it is important for all Universities to consider how to include students from a vocational educational background. However, as demonstrated above, admissions tutors, who undoubtedly recruit with integrity, have to be astute concerning the mathematical background of BTEC students and need to be fully aware of the unit content and profile of BTEC engineering qualifications. It is almost inevitable that the mathematical grounding, even with the Further Maths unit, will be weaker than A-level students and thus some extra support will be needed on arrival.

The survey reported in this paper represents only a snapshot of the situation in one region. Similar surveys elsewhere may reveal different results, though much of what has been discovered reflects staff experience of the BTEC student profile and confidence in maths. It also confirmed suspicions about the inconsistencies of assessment methods. Qualitative data will be gathered by interviewing new undergraduates this semester. Data from this next phase will further inform the support mechanisms at the university.

Higher Education Institutions are well aware they must accommodate the shortfall any engineering student may have with their maths. The work carried at UoS will continue to be pro-active to ensure students not only have the right opportunity, but will know that support will be available to help encourage success. Fortunately, the recent rapid growth in mathematics learning support mechanisms [5] seems to be providing much of the extra support that BTEC students need.

References

[1] Higher Futures Lifelong Learning Network for South Yorkshire and its travel to study area including North Derbyshire and North Nottinghamshire
Acknowledgements

The Heads of Engineering Departments at Doncaster College; Rotherham College of Arts and Technology; Barnsley College; Sheffield College; Chesterfield College; North Notts College

List of tables

Table 1 Group Mean Scores

Table 2 Topics with Mean Scores below Group Mean Scores