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Effectiveness of UK and international A-level assessment in predicting performance in engineering

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In many universities, admissions decisions are made based upon the advanced-level (A-Level) results. The purpose of this study was to assess the value of A-level and international equivalents as a predictor of early achievement in higher education. 135 UK and 92 international undergraduate engineering students from 35 countries were assessed at different stages of their instruction. The results show that the key predictor for academic performance is whether or not students received a British education. The implications are that more policies and awareness are needed in order to effectively support international students in engineering during their transitional process.

Keywords: A-levels, Engineering, predicting academic performance, international students.

Introduction

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In science, technology, engineering and mathematics (STEM) subjects, students are less likely to successfully complete their first year (Godfrey, Aubrey, & King, 2010; National Audit Office, 2007; Smith, 2011). With the increasing participation in higher education (HE) in the United Kingdom and an increasing number of students from overseas, the role of university admissions staff in selecting those students with the best potential to succeed is becoming ever more challenging. Admissions decisions are typically made based on grades obtained in three A-levels, with one or more of the subjects often prescribed as an additional requirement, while international qualifications are often "translated" into a UK equivalent. Implicit in this system is the assumption that A-level results are a reasonable predictor of HE achievement; however, there have been a number of concerns recently raised about the validity of this assumption (Lee, Harrison, Pell, & Robinson, 2008; Mellanby, Cortina-Borja, & Stein, 2009). This issue is of particular importance when considering the effect of internationalization within the HE sector (Morrison, Merrick, Higgs, & Le Métais, 2005; Rienties, Beausaert, Grohnert, Niemantsverdriet, & Kommers, 2012; Rienties, Luchoomun, & Tempelaar, 2013b).

There is mounting evidence that selecting (international) students and predicting academic success is a complex and difficult exercise (Adamson & Clifford, 2002; Fastré, Segers, & Gijselaers, 2008; Franssen & Nijhuis, 2011; Lee et al., 2008; Rienties et al., 2012; Rienties et al., 2013b; Rienties & Tempelaar, 2013). Early studies into possible predictors of academic success had focused primarily on the use of entry qualifications and earlier grades; see, for example, Sear (1983), and the review of Foy and Waller (1987). Within the engineering subject areas, Adamson and Clifford (2002) found that a student's A-level grades were a good predictor of both their aggregate year-end marks and their performance on a practical, third-year project, though this correlation became unreliable after three years. Common to these studies on academic progression is a small or moderate (though statistically

significant) correlation between student grades on admission to HE and the results achieved in HE, and that this correlation decreases toward the end of the degree courses. We argue that this is primarily the result of four phenomena.

First, it can be argued that there are substantial differences between secondary education (and A-level instruction in particular) and teaching at HE institutions (Biggs & Tang, 2007; Christie, Munro, & Fisher, 2004; Hoyles, Newman, & Noss, 2001; Mellanby et al., 2009). Because A-level curricula in England are standardized and are both developed and audited by a body external to the individual colleges or sixth-forms, they are necessarily fairly prescriptive. In addition, `hard' sciences such as mathematics and physics tend to be assessment-driven, as student achievement is easy to quantify empirically. There is evidence that these prescriptive, assessment-driven curricula tend to encourage superficial or rote learning (Biggs & Tang, 2007; Dochy, Segers, & Sluijsmans, 1999; Imam, Rafiq, & Kumar, 2011; Segers, Dochy, & Cascallar, 2003). HE admissions staff cannot distinguish between students who achieved high A-level grades through primarily superficial learning practice, and students with identical results but who were able to develop a deep, contextualized internalization of the material (Mellanby et al., 2009). Since HE courses aim to promote deep learning (Biggs & Tang, 2007), students are expected to have integration and synthesis skills, which are flexible enough to be adaptable to the HE learning environment.

Second, most studies on predicting performance of first-year engineering students focus on comparing A-level students to other local (UK) students (See for example Adamson & Clifford, 2002; Lee et al., 2008; Todd, 2001). However, to our knowledge, most studies have ignored the fact that an increasing number of engineering students are admitted with international qualifications (Luxon & Peelo, 2009; Morrison et al., 2005). For example, Morrison et al. (2005) used Higher Education Statistics Agency (HESA) data from 1995 and 2000 to compare academic performance amongst 260.000+ undergraduate UK and

international students and found substantial disciplinary differences. However, in engineering degree programmes, no significant statistical differences were found in the class of degree obtained between UK and international students. By comparing and contrasting UK students and international students having "similar" qualifications, we are able to provide a more comprehensive picture whether A-levels are appropriate starting qualifications for engineering. Furthermore, given the increased number of international students in engineering, widening the focus will allow us to provide more guidelines for university admissions staff to make appropriate selections given the more heterogeneous applications from (international) students.

Third, the phenomenon of grade inflation (or the gradual, national increase of student performance) has narrowed the distribution of A-level grades, so that it is becoming increasingly difficult for admissions tutors to identify top candidates from amongst all those achieving the maximum possible grades (McAllister, Jiang, & Aghazadeh, 2008; Todd, 2001). For example, in a historical study of academic performance on a standardized mathematics entry test in the period 1985-2000 at the University of York, Todd (2001) found that A-level students' performance significantly declined over this period despite the year-on-year increase in the A-level grades of the sample cohort.

Finally, an important distinction must be made between an HE applicant's previous achievement and future potential (Nijhuis, Segers, & Gijselaers, 2008; Smith, 2011). Differences in teaching and learning styles (Nijhuis et al., 2008; Struyven, Dochy, & Janssens, 2011; Tempelaar, Rienties, Giesbers, & Schim van der Loeff, 2012), student motivation (Adcroft, 2010; Tempelaar, Gijselaers, Schim van der Loeff, & Nijhuis, 2007), scope and subject matter (Tempelaar, Schim van der Loeff, Gijselaers, & Nijhuis, 2011), academic and social integration (Christie et al., 2004; Morrison et al., 2005; Rienties et al., 2012; Rienties et al., 2013b), cultural differences (Morrison et al., 2005; Rienties, Hernandez

Nanclares, Jindal-Snape, & Alcott, 2013a), and differences between secondary education instruction and HE may be reflected in student performance (Lindblom-Ylänne, Lonka, & Leskinen, 1999; Mellanby et al., 2009; Sear, 1983). One might argue that high-achieving students less able to adapt to deep-learning models will not be able to achieve at their previous levels, while students who had developed deep-learning habits earlier may have been disadvantaged by the prescriptive nature of the A-levels themselves and will tend to exceed expectation in the HE environment (Mellanby et al., 2009).

The purpose of the present study, then, is to examine what effects (if any) the A-level curriculum and international equivalents had on performance of students in a highly analytical HE course requiring functional knowledge, in light of the concerns listed above. A new feature of our study is that we will compare and contrast UK A-level students from students with "equivalent" entry qualifications from non-UK countries. A second new feature of this study is that we will focus on the effects of A-level grades on study performance beyond the first year, in order to determine whether A-level grades have a short-term or long-term impact on study performance.

Method

Sample group

Admissions data and HE grades were examined for a group of 227 students (192 male, 35 female) in their first and second year of degree courses in mechanical, medical, aerospace and civil engineering at a university in the south of England during the 2009-10 academic year. Of these, 127 (102 male, 25 female) were admitted on the basis of A-level grades obtained in the UK or at an international educational institution following the British system (and shall hereafter be referred to as the `A-level group'), and of these, all but 11 had obtained a

qualification in physics at A-level. Given contemporary debates on whether females under- or over-perform in physics (Smith, 2011), we explicitly included gender in our analysis. The others were admitted on the basis of postsecondary qualifications other than A-levels, and include students with BTEC, International Baccalaureate, Access or other international qualifications deemed by UCAS to be broadly equivalent to A-levels (UCAS, 2010). The sample includes those students who were re-attempting the module after having failed it previously, though the number of these is typically small ($< 5\%$). In total 135 students were from the UK, while 92 students were from one of 35 foreign countries. Most of these international students were present with only one to five co-national students, with the exception for students from Greece (25), China (8), and Cyprus (6). The sample also excluded those students who may have attempted some assessments but did not complete their first year of study.

A-level grades were assigned an arbitrary score for the purposes of numerical analysis. Grades of A, B, C and D were given, respectively, scores of 4, 3, 2 and 1. Grades below D were given a score of zero. Only those students who attempted A-level qualifications in a given subject were included in the statistics for that subject. Advanced subsidiary (AS) level qualifications were considered in cases where A-level grades were unavailable, though these represented less than 4% of the total sample. Table 1 compares the mean A-level scores for the sample group to the 2009 UK national average. It is important to note that the sample group outperformed the national average in all but one of the categories, and therefore represents a comparatively able cohort.

Insert Table 1 about here

Instruments

Mid-term and final test in Classical Mechanics. In order to assess the short-term retention of secondary education in a typical STEM subject, students were assessed after five and nine weeks of instruction in a classical mechanics module, as the module descriptors closely matched and built upon prior knowledge from secondary education. The five-week formative assessment consisted of a mix of conceptual and analytical components combined in multi-step problems. The nine-week assessment was administered as part of a longer, multi-subject examination which would have been perceived by the students as a high-stakes summative assessment. Both this and the mid-term assessment were carried out under timed examination conditions.

Academic performance after year 1 and year 2. The academic performance of the participating students was assessed after year 1 and year 2 by computing an average grade for all subjects studied, weighted against the number of credits associated with each module. This leads to an index between 0 and 100 (maximum possible score on each of 20 modules). Cohen's *d* was used to estimate and characterize the longitudinal effect by taking the standardized difference of the means; this metric is appropriate when the means of two groups are compared (Cohen, 1988). As a general, cross-discipline guideline, $d \leq 0.2$ indicates a small effect, $0.2 < d < 0.8$ indicates a moderate effect, and $d \geq 0.8$ indicates a large effect. To estimate the analysis of variance (ANOVA) effect size, the partial η^2 criterion was used, where $\eta^2 = 0.01$, $\eta^2 = 0.06$ and $\eta^2 = 0.14$ indicate a small, medium and large effect, respectively (Richardson, 2011).

Results

Comparison of performance in classical mechanics based upon entry qualifications

Table 2 shows the mean grade and standard deviation (SD) achieved on the mid-term (five-week) and final (nine-week) test scores in classical mechanics, for subgroups of students sorted by their entry qualifications in mathematics and physics. A general upward trend is apparent from other (non A-level) qualifications through to A-grade, with a strongly positive score for C-B students. However, there are large individual differences within each subgroup, as the standard deviations were typically half of the mean. Female students are also shown to score significantly higher on the two tests than male students.

A multivariate analysis of variance (MANOVA) of the mid-term and final test scores with the seven sub-groups of academic entry-qualifications ($\Lambda(6, 214) = 3.377$, $p < .001$) and gender ($\Lambda(2, 214) = 3.538$, $p < .05$), where Λ is Wilks' Lambda function and p is confidence or probability level. The MANOVA confirms the results, and shows that the effect was significant. Follow-up univariate analyses of variance (ANOVAs) indicate significant differences in mid-term test results in terms of gender ($F (2, 216) = 5.955$, $p < .05$) and prior qualification ($F (6, 216) = 4.633$, $p < .001$). Significant differences in final test scores in classical mechanics were found in terms of prior qualifications ($F (2, 216) = 4.786$, $p < .001$). Separate ANOVAs in terms of gender and exam performance in Table 2 indicate significant differences in performance based upon prior qualifications, with strong effect sizes.

Insert Table 2 about here

Comparison of academic performance after one and two years

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Table 3 compares the academic performance of the subgroups after one and two years of higher education, as measured by their weighted average year marks. A general increasing trend can be seen from other qualifications through A-grade for male students, with the notable exception of the D-grade subgroup, who performed at a similar level as A-grade students. For example, male students in the C-grade subgroup scored an average 8.56 percentage points lower than those in the A-grade subgroup. In general, female students scored significantly higher during the first year, with the exception of those in the B-grade subgroup. After two years, the same trend is observed for male students, though the B-A grade subgroup outperformed the A-grade subgroup. Again, a MANOVA of the first and second year weighted average year marks with the seven subgroups of entry qualifications ($\Lambda(6, 209) = 4.293$, $p < 0.001$) and gender ($\Lambda(2, 209) = 0.894$, *not significant*) confirms the results, and a significant effect was found for the case of entry qualifications. Follow-up univariate analyses of variance indicate that only prior qualifications significantly predict first year performance ($F (6, 217) = 7.797$, $p < .001$) as well as second year performance (F (6, 216) = 6.594, p < .001).

Insert Table 3 about here

In Table 4, the key Pearson correlations for nominal variables and Spearman Rho correlations for categorical variables are illustrated. Both the mid-term and final examination scores in classical mechanics are positively correlated with A-grades. Also, academic performance after year 1 and year 2 are positively correlated with A-grades. Our proxy of mean entry qualification is positively correlated with all variables involved. These results indicate that prior qualifications, in particular A-grades, are moderately related to academic performance, both after one and two years of study. In Table 5, the academic performance

differences between UK and International students are illustrated. UK students in general outperform international students in classical mechanics and academic performance after one and two years, with moderate to strong effect sizes.

Insert Table 4 about here

Insert Table 5 about here

Finally, regression analyses of academic performance after one and two years show that following British education is the primary predictor of academic performance in Table 6. That is, only in Model 1 A-grades significantly predicts academic performance, while in the other five models A-grades is not a significant predictor. As one would expect, performance during the Classic Mechanics module significantly predicts performance after one year, but British education remains a significant predictor in Model 2. After two years, having followed British education continues to be a significant predictor of academic performance, while A-grades education does not significantly predict academic performance as highlighted in Model 3 & 4.

Insert Table 6 about here

Discussion and conclusion

In this paper, we examined the effects of the A-level curriculum on academic performance in engineering, considering both short-term performance (in the form of grades achieved in one core module) and long-term success (in the form of weighted average grades after one and

two years). A new feature of our study was that we compared and contrasted UK A-level students and students with similar qualifications from other countries. We found that academic performance typically follows a positive trend from D-grade to A-grade as one would expect, irrespective of gender. In line with previous studies, we found positive correlations between A-level grades and performance in a particular core module and academic performance after one and two years.

Follow-up correlation analyses between prior qualifications and academic performance indicated that A grades on entry qualifications were positively correlated with first and second year academic performance, as was found before by Adamson and Clifford (2002). However, follow-up regression models showed that primarily British education was the key predictor for academic performance, rather than pre-HE student grades. In contrast to findings by Morrison et al. (2005), international students performed significantly lower on the various assessments than UK students, indicating that prior education and/or academic and social adjustment for international students was not well-aligned with the requirements of UK undergraduate engineering degree programmes. One possible explanation for the significantly lower performance of international students is that UK undergraduate programmes in engineering require learning styles which are different from those with which international students may have become familiar in their home countries (De Vita, 2001; Joy & Kolb, 2009; Tempelaar et al., 2012). De Vita (2001, p. 167) refers to this as cultural learning style, 'which re-proposes learning as a culturally-based phenomenon may then explain why teaching methods, learning tasks and environments which promote learning in some cultures may be ineffective in others'. While Morrison et al. (2005) conducted data analyses of completed degrees using data from 1995 and 2000, our analyses of data collected in 2010/2011 were focused on the first two years of academic adjustment and performance. A possible explanation of this difference in findings is that perhaps at the end of the study, the

majority of international students have adjusted their learning style to perform similar to British students, or alternatively international students who fail to adjust may decide to withdraw and are therefore not included in HESA degree classification statistics.

Limitations and future research

The first limitation of this research is that it is based upon academic performance and prior qualifications, and both of these indicators are proxies of learning and prior expertise. Although a large body of research assumes that academic performance on exams is the key indicator of learning (Dochy et al., 1999; Nijhuis et al., 2008), recent research has highlighted that teachers and researchers should broaden the focus to encompass learning both inside and outside the classroom. Also, prior qualifications do not exclusively reflect the expertise, experience, knowledge, skills and attitudes of students, as was already illustrated by Fastre et al. (2008). A second limitation was that the factors that measure the barriers and facilitators of learning processes within engineering were not considered. For example, Rienties et al. (2012; 2013a; 2013b) found that academic and social integration, or the extent to which students feel that they are part of the way of life at university, is an important predictor of academic success amongst first-year undergraduate students. Finally, as we found strong differences between UK and international students, further research is necessary in order to understand whether there are certain groups at risk amongst international students that would require more attention than others. In the near future, by extending the database we hope to be able to fine-tune our modeling in order to understand which students are struggling more than others, and thereby provide more tailored support when necessary.

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